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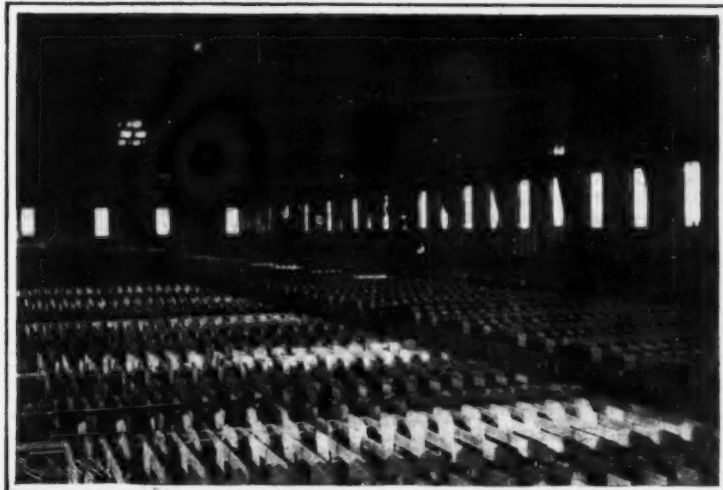
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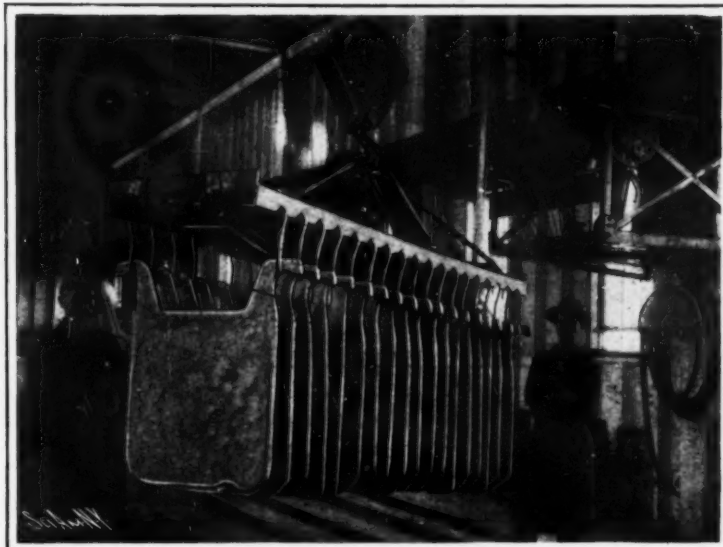
CONVEYING SLAG TO REFUSE PILE BY ELECTRIC TRAM ROAD.



WHERE COPPER IS ELECTROLYTICALLY SEPARATED FROM ITS ORES.



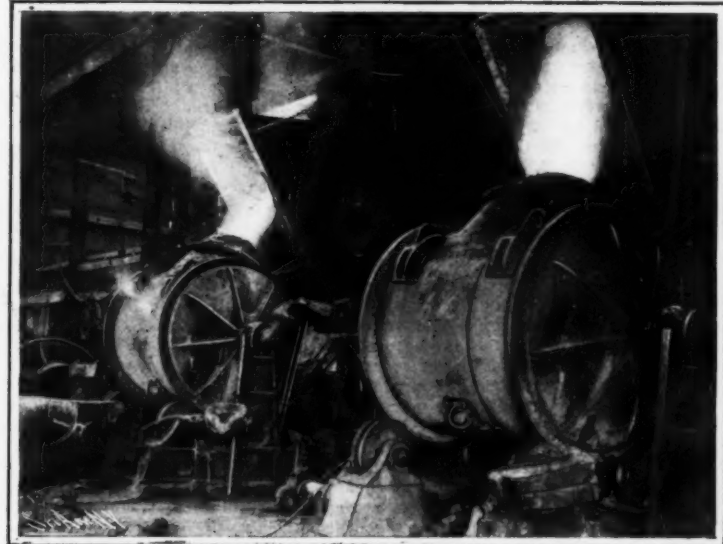
THE CIRCULAR SLAG-CASTING MACHINE.



REMOVING COMPLETED ANODES FROM THE BATH.



TRANSFERRING THE COPPER FROM THE ANODES TO THE CATHODES.



OXIDIZING THE COPPER IN CONVERTERS.

THE EXTRACTION OF LOW-GRADE COPPER ORES.

THE EXTRACTION OF LOW-GRADE COPPER ORES.*

By DAY ALLEN WILLEY.

In the most modern processes employed for extracting copper and the precious metals from concentrated ores, the elements of heat and electricity are almost indispensable. While the first commercial plant for the electrolytic treatment of copper alloy has been in operation in this country less than thirty years, no less than one-half of the metal produced in the United States passes through the electrolyte process, and one-third of the world's supply of refined copper. The mechanism which has in recent years been perfected has reduced the cost of refining copper from about \$20 per ton to less than \$8 per ton. For this reason the principal refineries in the United States have electrolytic departments in connection with the other apparatus for treating the concentrates by the dry or converter processes.

In referring to the works at Anaconda and Great Falls, Mont., Baltimore, and El Paso, the smelter which has recently been completed at Tacoma, Wash., should be mentioned, since it contains what is probably the most modern devices in this country for metal extraction. It not only treats copper but lead ores with such success that concentrates containing less than one per cent of pure metal can be profitably worked. Securing material from the mines of British Columbia, Alaska, California, Oregon, Mexico, as well as Central and South America and Europe, over thirty varieties are roasted in the Tacoma smelter, the charge at times including a blend of five or six different grades. The skill in mixing the ores is one reason why it is profitable to extract the metal from very low grades, but the various processes employed are notable for their economy.

The concentrate furnace in the copper plant is of the Allis-Chalmers type, and has a maximum capacity of about 350 tons every twenty-four hours, the tonnage

bath is tested daily, as it is necessary to maintain the proportions as exactly as possible. Each cathode is of course set in the tank next to the anode from which it secures its supply of copper, each set of anodes constituting an electric circuit. The necessary connections are made between the various tanks by copper conduits. In operation the current enters a tank through the anodes, then passes through the solution to the cathodes, the space between anode and cathode being a little over one inch. From the cathodes the current passes to the anodes, which are insulated from the negative conductor of the adjoining tank. It then goes through the bath and the cathodes of this tank, and so on to the third tank, where the process is repeated, transferring the metal as in the electro-plating process.

The gold and silver which may be held in the anode are precipitated to the bottom of the tank in the form of a black slime. In securing these metals the slime is first run through a screen, then placed in a vat lined with lead containing a solution of 25 per cent sulphuric acid and 75 per cent water. Into the bath hot air and steam are injected. Application of this treatment for eight or nine hours dissolves the impurities in the material, and they are removed with the solution from the slime, usually by syphoning. The latter is then dried on iron pans in a hot-air chamber, and the gold and silver separated from it in the lead refinery.

Despite the variety of low-grade concentrates which it treats, the smelter at Tacoma produces copper which is practically without a trace of impurity, in addition to securing all of the gold and silver which may be contained in the ores. The lead smelter adjoining it has a capacity of treating 300 tons of ore daily, with an average production of about 1,000 tons of lead per month.

In the various operations in the production of copper at this plant, an electric current representing over 2,000 horse-power is required. For the electrolytic department a current varying from ten to fifteen amperes



POURING OFF SLAG FROM ROASTING FURNACE.

At the left is the conduit for molten metal and receiving ladle.

THE EXTRACTION OF LOW-GRADE COPPER ORES.

of copper obtained ranging from 30 to 43 tons, in addition to the gold and silver secured. The furnace is divided into two sections, one elevated slightly above the other for convenience in removing the slag, the latter being discharged into ladles mounted on trucks. The metal itself is poured into another ladle, which is taken to the converting department. Here it is run through cupolas, thence poured into tilting converters, where it is subjected to an air blast. The process is similar to the manufacture of Bessemer steel, and the product remaining, though crude copper, contains a very high percentage of pure copper.

From the converters the metal is conveyed to rotary furnaces heated by fuel oil, where it is melted to be cast into anodes of alloy for electrolytic treatment. From the latter department it is returned to the furnace department in the cathodes of pure copper to be again melted and cast into ingots for commercial purposes.

Nowhere has the electric current been utilized in a more remarkable way than in the separation of copper from the precious metals. To study the action of the current in transferring the metal from anode to cathode is indeed fascinating. The length of time usually required to reduce the anode to merely a fragment of metal so thin that it cannot sustain its own weight, is between twenty and twenty-four days. During this period the action of the current has literally built up the corresponding cathode, so that from a sheet of copper but a twenty-fifth of an inch in thickness, and weighing a few pounds, it may be over an inch in thickness, weighing 250 to 300 pounds.

The tanks utilized for this process are constructed of wood coated with metal to prevent them from being affected by the electrolyte. In the Tacoma plant they are about three feet in depth. The electrolyte is merely a solution containing about 16 per cent of blue-stone and about 5 per cent of free sulphuric acid. The

to the square foot is employed, the volume of current depending upon the proportion of silver and gold in the alloy, as well as the percentage which may remain of impurities. Should the latter be high, too much current density would force some of the silver as well as arsenic which may remain into the cathode, thus affecting the quality of the copper. In current distribution less than half a volt is required on the average to each tank. The current is conveyed to this department by means of ten cables, five of which are positive and five negative, the current being transformed at the plant from 40,000 volts to 100 volts. All of the electricity is secured from the generating plant in the foothills of Mount Tacoma, and brought by long-distance transmission line a distance of nearly forty miles. Another interesting feature of the plant is the immense chimney, which was erected for the purpose to carry away the gases expelled in roasting the various concentrates. This is the highest chimney yet to be constructed of steel and concrete, extending a distance of 306 feet above its base. It is located about 3,000 feet from the furnace, the gases being conducted to it through an immense wooden flume.

The electric current is also utilized for removing the slag as well as ingots, the cars being hauled by 7-horse-power motors. The furnaces and converters are served by a 20-ton electric traveling crane, another being employed in the electrolytic department for serving the bath. Interesting apparatus in connection with the smelter department proper is a circular slag-casting machine. It is equipped with 144 tilting molds, having a total capacity for 20 tons, and is driven by a 20-horse-power variable speed motor. The machine was devised by Mr. B. H. Bennetts, of Tasmania, general superintendent of the Tacoma works.

The proprietors of the Allan Line are arranging for the construction of two other new turbine steamers for the Liverpool and Canadian service.

[Continued from SUPPLEMENT No. 1563, page 25027.]

USE OF GAS FOR POWER AND HEATING.—II.*

By ERNEST A. DOWSON.

MANY engineers have thought that the power obtained from an engine working with gas plant of the "suction" type would be much less than if the gas were supplied under pressure. This, however, is not the case, and an inspection of a batch of indicator cards taken from engines of various makes, the sizes varying from 30 horse-power to 100 horse-power, shows in each case a mean pressure of from 80 to 90 pounds per square inch. In discussing the point with users of these plants, the author has often changed the engine over from the normal working under "pressure," to working by "suction" alone, without easing the load, notwithstanding which no change was noticed by those in charge. On this system it is not always essential that each gas engine shall have a separate plant. Provided they are fairly close together, two or more engines may be coupled up to the same generator. It is, of course, necessary to consider their relative locations, and to design the connecting main services with care. This "suction" type of plant has been erected in conjunction with various makes of engines, both at home and abroad, to the extent of over 10,000 horse-power, apart from any of those now supplied by Continental and other makers. For moderate powers, say from 10 horse-power to 300 horse-power, where no exceptional requirements have to be met, it offers many advantages.

The fuel consumption is extremely low, as instance by tests which have shown a figure as low as 63 pound per B. H. P. per hour of small anthracite of commercial quality, such as can be obtained in Birmingham at about 18s. per ton. The water required for gas making and cooling does not exceed about 4 pints per hourly B. H. P. Beyond this, an allowance for attendance must be made, and for a plant of, say 100 B. H. P., the time required is about 2 hours daily for one man. The small space occupied is also an important feature, and this is, roughly, equal to about half a square foot for each B. H. P. capacity. Installations of this type of plant are at work where the power is utilized in driving dynamos, supplying current for both electric lighting and power, and the fact that the whole station costs have worked out at from 1/4d. to 3/4d. per unit shows the really remarkable economy of the system.

As the most modern, the "suction" type of plant has naturally commanded much attention. This is a very interesting type of apparatus, and, as has already been indicated, it has much to recommend it for medium powers. At the same time, there are many cases where one or other of the alternative types should be adopted in preference.

For special cases, and where gas is required to serve the double purpose of driving engines as well as for carrying out heating processes on a moderate scale, an apparatus of what may be called a "combined" type is often used. On this system a portion of the gas is passed into a small gasholder to supply the blowpipes or burners, while the rest is sucked away direct to the engines. This arrangement economizes space, and has other features to recommend it where various kinds of work are carried on.

The particular kind of gasmaking plant to adopt in any given case can only be decided upon after a careful review of the special conditions under which it will work. There are usually quite a number of these conditions, each of which has an important bearing on the success of the scheme. The most economical results can only be realized by treating each case on its merits and giving full weight to all local considerations, so that it is impossible to lay down any hard and fast rule as to what is best in all cases.

The use of semi-water gas plants has proved so successful that apparatus of this type is now being constructed by various firms, but the foregoing general remarks will sufficiently describe the various principles involved in their operation.

Great confusion at present exists in the public mind as to the various gases and their uses. This point has already been touched upon in reference to the term "producer gas," but the additional terms "suction gas" and "pressure gas" are even more indiscriminately adopted. One has had frequently to explain that these terms are purely arbitrary, as the gases employed in the three cases may even be identical in composition! All gases made in modern power plants are of the "semi-water" class, and whether the steam and air are forced through the fuel by the pressure of the atmosphere, or whether the pressure is set up by a special blower, makes but little difference to the gas evolved.

It is of interest to note that the gas engine is now being adapted to the running of motor vessels. The first installation recorded was that of a canal barge, which was fitted with gas engines and plant of the "suction" type by Herr E. Capitaine, of Frankfurt. Gas engines are, however, somewhat heavy in proportion to the power developed; this and other points militate against their use for the purpose on more than a moderate scale. Great developments are sure to follow in this direction, and the little joke recently published in one of our daily papers, to the effect that our ocean liners are likely to become "merely floating gasometers," though not literally correct, may be found to be justified by events.

The above general remarks also apply to the driving of motor cars on the same system. There are a good many knotty points to be overcome before fast passenger cars can be run on gas.

* Abstract of a paper read at the Birmingham Association of Mechanical Engineers.

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT

senger vehicles can be dealt with, but the heavier class of lorries for transporting goods provide a field in which we may expect some progress.

Reviewing the practical working of gas engines, we note that Dr. Otto's method of compressing the explosive mixture is in general use, although the cycles of some of the engines, especially the larger ones, have been modified in recent years in accordance with the ideas of Clerk and other designers.

There are now two distinct cycles in use. The first, known as the "four-stroke" cycle, was first outlined by M. Beau de Rochas in 1862. It was not, however, until 1877 that the principle was put into operation, when the first Otto engine was constructed; hence the four-stroke cycle has been generally spoken of as the "Otto."

In order to obtain an impulse for every outstroke of the piston, which increases the power of an engine, and makes the turning moment more regular, the "two-stroke" cycle was devised by Clerk in 1880. To obtain the desired result it is necessary to employ a separate pump or pumps for introducing the charge into the power cylinder.

While all present-day engines operate on one or other of these two distinct cycles, there are nevertheless quite a number of special arrangements of pistons and cylinders, which are adopted by various British and especially Continental makers of large engines. It will be impracticable here to detail all these diversities, but they may be roughly classified as follows:

(1) Single-acting "four-stroke" (or Otto) cycle, with one or more cylinders.

(2) Double-acting "four-stroke" (or Otto) cycle, with one or more cylinders.

(3) Single-acting "two-stroke" (or Clerk) cycle, with one or more cylinders.

(4) Double-acting "two-stroke" (or Clerk) cycle, with one or more cylinders.

The early two-stroke engines were of the single-acting pattern, but they were only of small size. Owing to its greater simplicity, the Otto cycle has been universally adopted for all but the largest powers. Where large engines have been designed on the two-stroke cycle, which is now being further developed, they have almost always been double-acting. The leading exception is the Oechelhäuser.

It is well known that in all gas engines of large dimensions the greatest troubles experienced are those arising from the high flame temperature incidental to the explosion. Rapid cooling of the charge must therefore be resorted to in order to protect the working parts. The aggregate of the expansion of the metal forming the combustion chamber and cylinder becomes, in a large engine, a very appreciable amount. It is therefore extremely advisable to leave all this metal as free to expand as possible. This is, however, rather a difficult problem, as, taking the combustion chamber for instance, the inlet and exhaust ports, together with others for the ignition apparatus and the starting apparatus, must in any case be provided. For this reason valveless engines, such as the Oechelhäuser, are easier dealt with in this particular.

Continental makers of large gas engines have gone in for great elaborations in the way of water cooling in order to get rid of these temperature difficulties. With great ingenuity they have arranged to water-cool the pistons and piston rods in the double-acting engines, in addition to the ordinary cylinder jacket. The exhaust valves and their casings are also ingeniously water jacketed in most of these engines. It need hardly be pointed out, however, that the many complicated devices thus needed introduce additional risks of failure, and it is reasonable to look upon them as a merely temporary endeavor to make a working engine of large power. In view of these facts it really appears to practical engineers that the best way of building such an engine is to replace the large single cylinder by several of moderate size, say three or four, each of which we know from experience is capable of being worked over long periods without any chance of breakdown. In support of this view it may be noticed that there is a decided feeling among many of the most important gas engine makers in the country in favor of the adoption of such an arrangement for large powers.

Before leaving the matter of high temperature difficulties in large engines, just touched upon, it is impossible to omit speaking of the advances which have been made during the last twelve months at the instance of Mr. Dugald Clerk, M. I. C. E., the eminent gas engine expert, who recently described his work in this connection before the British Association. Mr. Clerk's principle has been adapted, in the first instance, to an engine working on the four-stroke cycle. After the suction stroke of the engine has been completed and the whole of the explosive charge drawn in, the ordinary admission valve is closed, and through a secondary inlet an inert diluent is introduced in such a way as to stratify with the charge, and not to mix with it to any serious extent. The diluent may be either air or cooled exhaust gases. Compression afterwards takes place, and the charge is ignited in the usual way. The presence of the diluent serves to average down the flame temperature to an extraordinary degree, and a cool working engine is obtained without any other cooling than that of the ordinary cylinder jacket. Furthermore, the power developed in a cylinder of given size is increased, with a correspondingly higher thermal efficiency. The practicability of these ideas has been demonstrated in an engine of 300 I. H. P., constructed by the National Gas Engine Company, Ltd., of Ashton-under-Lyne. This engine has now been at work for some months in a Lancashire mill, using

water gas as fuel, and the author is informed by Mr. Clerk that it is running very satisfactorily and smoothly, notwithstanding the nature of the fuel.

An alternative scheme is that arranged by M. Banki, a Continental engineer. On this system a few drops of water are sprayed into the cylinder during the suction stroke. This keeps down the temperature so that, even with coal gas, a compression of 200 pounds per square inch may be used without fear of pre-ignition; a higher thermal efficiency may therefore be obtained. I am not aware that any large engines are working in this way, and it remains to be seen whether the introduction of water will give rise to practical difficulties, such as defective lubrication, corrosion, etc. Messrs. Crossley Brothers have adopted the system, and further experience in the matter will demonstrate its exact value.

One important feature which has greatly contributed to the successful working of large engines is the improved form of ignition arrangement. The old hot-tube ignition is now generally discarded on such large engines and an arrangement of firing the charge electrically is adopted with much success. The great advantage of this system is that the spark can be introduced well into the combustion chamber of the engine in the presence of the gaseous mixture, and no narrow passages are needed as is the case with the hot tube. A very favorite method is the use of a low-tension current, generated by a magneto machine of the Simms-Bosch pattern.

With reference to the many diversities of heating work, it is a little difficult to know what to select for mention, as the field for the application of gaseous fuel to heating is even wider than that of motive power. One may say, however, in the first place, that almost all heating processes now carried out with solid fuel may be better done with gas. (Here we will not wait to theorize on the fact that all fuel must become gaseous before it will ignite, as we are now dealing with gases supplied, as such, from separate pieces of apparatus.)

As has already been insisted upon in connection with power plants, it is necessary to exercise a good deal of judgment in each case as it occurs, and this is even almost a stronger necessity where heating is required. In the first place, it is necessary to decide whether or not the installation of a gas plant is justified by all the circumstances. Obviously, if any given appliance, at present coal-fired, shows a very high thermal efficiency, one has hardly a *prima facie* case for recommending the change. Of course there may be other incidental reasons for deciding in the affirmative, such, for example, as increased convenience and cleanliness, reduced attendance, etc., and these last named are frequently very important. Even when one has decided on the change, open questions still remain, not only as to the "make up" of the gas plant, but also to the exact way in which the gas shall be applied to the work in view. The method that gives good results in one case will perhaps totally fail in another, and this has brought it about that in some instances failure to effect the hoped-for economy has led users to discard gas firing as a failure altogether. This need never occur if the normal "working programme" has been carefully considered from the outset, and the heating appliances properly designed.

It may be said without hesitation, that very large savings may be effected in this direction by most manufacturers, if the matter be dealt with as just described. The actual saving to be realized, as compared with the use of either solid fuel or of coal gas, varies from, say 15 per cent to 75 per cent, according, of course, to the more or less efficient nature of the present system. Much also depends on the scale of working.

Apart from any direct saving, however, the adoption of gas firing enables us to have a much better control of the temperatures in our furnaces, while the more perfect combustion which is effected is most important. Not only do we entirely eliminate the unpleasant discharge of smoke, but also the heavy oxidation and scaling of the metal work under treatment, at present a fruitful source of loss, especially in the case of light stamped goods.

In the field of the larger industrial applications we owe a large debt to the late Sir William Siemens, as the principle of "regeneration" (so called: this should be described as "recuperation") he introduced has quite revolutionized many of the processes carried on, and this has been adapted to many types of furnace, enabling them to be heated with the utmost economy. The Siemens type of regenerative furnace has been universally adopted for steel making. Originally such furnaces were fired with air gas, made in a producer designed by Siemens himself. This fuel was later on replaced, for this special application, by semi-water gas, which is still largely used in Siemens furnaces for other kinds of work. For steel welding, however, this gave way in its turn to water gas. Earlier in this paper the manufacture of water gas was briefly described, and for carrying out the above and other special processes involving high temperatures, it is well adapted.

Turning again to the use of semi-water gas, as first devised in the original Dowson apparatus, it may be pointed out that, although the heat value of this gas is lower than that of water gas, say 160 B. T. U. per cubic foot, it is by far the simplest and cheapest to produce of any of the specially-formed gases. For all purposes, except heavy welding and the few special processes just mentioned, it is the most suitable gaseous fuel to adopt.

Dowson gas may be made from either semi-bitumin-

ous coal, or from anthracite or coke, according to the locality and the class of work to be performed.

The crude gas as made for heating costs from about $\frac{1}{4}$ d. to 2d. per thousand cubic feet, according to the scale of working, the class of raw fuel employed, and whether it has or has not to be cleaned before using. As, however, four times the volume is required to perform any work for which a given volume of town gas would suffice, its cost would be actually equal to the latter if supplied at, say 3d. to 8d. per thousand. It is needless to point out that it is impossible to obtain town gas at even the latter price.

There are several methods of supplying gas to its many uses in industry, these being dependent, as aforesaid, on local and varying circumstances. As an instance, the use of gas holders, or their entire elimination, may be mentioned. It is quite possible to work without them in all cases by certain adjustments of the working pressures, and by using some form of valve or disk governor, where such an appliance is called for. Nevertheless, the author favors the adoption of a gas-holder, at least in cases where the same plant serves both power and heating, although it is not usually essential that the gas-holder should be a large one, yet this appliance forms quite the simplest and surest form of governor that has been devised. Another detail is connected with the use of natural or forced draft for the air supply to the flames. This depends upon whether we require a high local temperature, or a less intense, though more distributed heating effect, and in some cases, also, on the design of the furnaces.

Temperature of over 2,000 deg. F. can be obtained in a crucible furnace with Dowson gas without using any air blast, and taking the gas quite cold from the main. Much higher temperatures than this can be obtained by using an air blast, and this will be appreciated when the author records the fact that he has seen a wrought-iron bar run down into a plastic condition under the influence of a blast flame using superheated gas.

For the larger industrial applications it is usual to construct the furnaces on the regenerative system, although these may generally be of the "continuous" order, without recourse to the principle of reversing currents usual in the Siemens furnaces. The gas itself is taken hot, direct from the generators, without passing through any system of scrubbers. For this class of work it is usually best to employ bituminous coal for the gas making, one reason being that we thus get the benefit of radiated heat from the luminous flame obtained. If possible, it is also well to utilize the sensible heat of the gas itself, and to this end the gas generator should be placed fairly close to the furnace to be heated. For the above and other reasons it follows that semi-water gas supplied from a distant central station is anything but a good fuel for large furnaces. Of necessity it would be supplied quite cold, and as the hydro-carbons have been almost entirely eliminated the flame affords little radiant heat. For the generality of work this system is neither economical nor efficient, and cannot compare with the use of self-contained installations.

There are some large installations of Dowson plant in South Staffordshire where the gas is employed in heating ranges of brick-built ovens for annealing malleable and common iron castings. In other cases it is employed for the heating of boiler plates, tube tempering, etc. It is also very suitable for hardening cycle parts, and a notable example of this application is to be seen at the Birmingham Small Arms Company's works, where a battery of some forty furnaces is in constant use.

Among the many other purposes for which gas is adapted is its use for warming of workshops, etc. Usually the simplest method is to work in conjunction with the circulation of warmed air, and in the case of large open buildings this has much to recommend it. The Basingstoke works of the Dowson Company have been heated in this way for the past five years, the gas being utilized in a heater of special design.

The whole subject of gas firing is of extreme importance, and in this connection the words of the late Sir William Siemens, F. R. S., may be cited: "I consider it positively barbarous to use coal for any purpose in its crude state, and believe the time will come when all crude fuel will be separated into its component parts before it reaches our habitations."

In order to further the realization of his views, the same authority gave a special prize for "The best method or arrangement for utilizing fuel as a heating agent for domestic and industrial purposes, combining the utmost economy with freedom from smoke or noxious vapors." At the London Smoke Abatement Exhibition, this prize was subsequently awarded to a semi-water gas plant of the type already described.

The population of twenty of our largest eastern cities and their contributory territory will aggregate 15,000,000 people. Both population and wealth are constantly increasing, and in consequence there is a growing demand for something more than the mere necessities of life. Fruits, flowers, and vegetables are needed to meet the requirements of life, and these, to be furnished at their best, must be grown for the most part close at hand and produced in such a way that the largest return can be secured from a given area of land with a minimum risk. To accomplish this result it must be practicable to control to a large extent climate, soil, moisture, temperature, and, in a measure, light. The only way this can be done successfully and practically is through the medium of glass houses.

WHY CASTINGS CURVE.

If there were no shrinkage in metal during cooling there would be no curving. But exactly why or how curving happens in one direction rather than in another, is not always clear, even to the molder. There are plenty of straightforward jobs in which it is safe to say that curving will occur in one particular direction. But even then, apart from previous experience, a man is unable to say to what extent a casting will "go." A molder's judgment, or instinct, or call it what you like, is the only available guide in new work.

If a casting has a thick flange or flanges on a thin web, as in Figs. 1 to 5, it is absolutely certain that, though the patterns are made straight and the molds are also true, the castings will, if left covered up until cold and then turned out, be concave along the faces marked A, never convex. The reason is that as the lighter and heavier portions cool faster and slower respectively, they exercise mutual coercion. The thin cools off first and draws the thick with it. What happens afterward depends on proportions and conditions. The thick may pull the thin back, or it may remain permanently distorted. But neither portion, speaking generally, shrinks to precisely the same amount that it would do if untrammelled by an adjacent portion of different cross-sectional area.

Though this appears to be the correct explanation, yet it must be added that it is often very difficult to feel quite satisfied in regard to the causes of curving in some particular cases. One must look a little deeper, and perhaps theorize a little to find a reason for some examples of curving.

Curving is intimately related to the crystallization of cooling iron, and the latter helps us to understand what goes on in a casting during the process of curving. If a casting of any considerable mass is fractured across through the center, invariably the largest crystals will be found in the middle of the thickest mass of metal. And when metal is chilled rapidly, the crystals are much smaller than when cooled slowly. In consequence of this, a certain amount of mutual accommodation of adjacent parts of shrinking castings exists, and this serves to explain some of the apparent anomalies in shrinkage. It explains also the fact that the founder can obtain close-grained, or very open-grained castings by different treatment, as by pouring hot or cold, cooling rapidly or slowly.

In very massive castings the crystals become actually torn away from the central hotter portions by the shrinkage of the outside rigid colder parts, leaving either sponginess, or actual open spaces about the center, devoid of metal. Such being the case, it is easy to understand how portions of castings are able to exercise strong coercion upon parts adjacent, subjecting them to distortion; and again how the molder is able to interfere with and modify the natural movements of castings.

Referring again to our simple examples in Figs. 1 to 5, the proportioning there illustrated should be noticed and compared with that in Figs. 6 and 7, neither of which last will go curved in any direction. In these, though the sections A and B do not cool uniformly, the shrinkage is practically equal; in the first examples it is not. The theory is this: In Figs. 1 to 5 the thinner web, or the thinner flange as the case may be, cools down quickly, the thick flange remaining red hot for some time longer. The same thing happens in Figs. 6 and 7, but the same results do not fol-

low in each case. The reason lies in the crystalline character of the metal, in consequence of which its shrinkage can be delayed or accelerated, with resulting differences in the coarseness or fineness of grain of the crystals.

What happens when the castings in Figs. 1 to 5 curve is this: The thin web shrinks first and becomes black hot, while the larger web, or the broader flange, A, remains still red hot. As the latter has not then shrunk very much, it *retards*, to some extent, the shrinkage of the colder part adjacent, so that the 'at-

ter does not shorten quite so much as it would if it were unattached to the larger web or flange. When the latter cools down, however, it shrinks nearly to its full extent, and its greater mass carries with it greater strength of coercive power than the thin web possesses. It is, however, still held in bondage along the plane of its union with the web. It shrinks therefore less there than along its outer, untied edge, and thus assumes the only form possible under such circumstances—

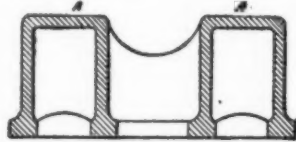


FIG. 12.

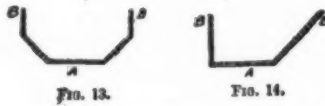


FIG. 13.

FIG. 14.



FIG. 15.

namely, a curve of which the outside edge forms the shorter arc.

But in the second example, Fig. 6, the web, B, is much broader than in the first examples, and its greater width enables it to resist the pulling effort of the cooling flange, A; that is, the web masters the flange, so that the latter cannot curve, but instead, its crystallization is left of coarser, more open grain—a fact which is evident on fracture. In the case of the double-flange casting, Fig. 7, the tendency of each flange, A A, to curve is resisted by the other, the pulling forces due to cooling being equal and opposite.

And what happens when castings break in cooling is of the same nature, and due to the same cause—namely, the differences in rates of shrinkage of adjacent parts. So long as such parts are not tied fast to one another, they will not break from differences in rates of shrinkage; but when they are subjected to a large amount of shrinkage beyond that to which the crystals are able to accommodate themselves, the sections part company. In many cases, too, safety from fracture lies in the capacity for curving, the only alternative being rupture of the crystals.

Though in the double-flange casting in Fig. 7 no curving occurs, yet when one flange is made considerably heavier than the other, as in girders, concavity takes place on the outer face of the heavier flange. The reason for making this difference in the sectional areas of top and bottom flanges is due to the difference in the tensile and compressive strengths of cast iron, and receives its chief exposition in cast-iron girders. But the puzzling point is that the degree of curvature is varied much by differences in depth and in length of girders. These differences cannot be put into a formula; but patterns often have to be corrected for curvature after the first casting is made. Invariably,

Short girders, if of the sections in Nos. 2 and 3, would show little curvature. It is increased with length, simply because greater length gives more scope for the curvature to show itself. In trying to account for these differences, we have to consider relative flange areas, depth of web, and web thickness—each of which, separately, and relatively, affects the ultimate shape of the casting.

The sequence of events in the cooling of a girder is this. The thin flange parts with its heat to the sand adjacent, and cools most rapidly, together with a portion of the web that lies adjacent. But an essential point to remember is that it does not shrink to quite its fullest natural extent, being held in some degree by the heavy flange and by the heavy portion of the web next it.

Then these latter portions continue to shrink after the thinner parts have become comparatively cool, though far from cold, and so they become shorter than the inner parts, with resulting concavity on the outer face of the thick flange. This is what generally happens. This is a point of much importance, because it is apparently anomalous that a thick piece of metal should shrink to a greater extent than a thin one, for all foundry experience goes to prove the contrary, as any molder or patternmaker may soon prove if he takes the trouble to measure patterns or molds of light and heavy sections and then their castings. The shrinkage of the first will average $\frac{1}{8}$ inch in 14 inches or 15 inches, that of the latter $\frac{1}{8}$ inch in 16 inches to 20 inches.

But though castings of thin section shrink more than massive ones, we find that in the examples here given the thick portions shrink more than the thin ones adjacent, as indicated by the hollow curvature along the thick edges.

The apparent anomaly is not difficult of explanation, being due to the accommodating character of the crystals of iron, which allow themselves to be pulled one way or another along the lines of least resistance. The thin metal cools off rapidly first, with fine crystallization; the thick cools slowly, and is coerced by the former, and then the crystals are large, or open-grained. But the full or natural shrinkage of the thin metal does not take place because it is not entirely free and unfettered, but held in bondage by the adjacent mass. And as it is not quite cold at this stage, it does not shrink, for that reason, as though it were alone. The process is a rather involved one, but this explanation squares with the observed facts. It also explains the differences in curvature that are produced by varying the proportions, as in Fig. 8. When curvature does not take place, or only in a slight degree, this is due either to a lesser disproportion between the cross-sections of the flanges, or to the presence of a deep and heavy web. Lessened disproportion brings the flanges nearer to that equality in dimensions which we noted in Fig. 8, No. 1, where the tendencies to curve are equal, and opposite. It is mainly with a view to avoid such disproportion that cast-iron girders are seldom, if ever, made with flanges proportioned in the ratio of the tensile and compressive strength of cast iron, namely, about 1 to 6; but 1 to 3, or even less, is near the usual practice.

A deep and heavy web lessens the tendency to curving, the writer believes, by acting as a carrier of heat from the thick to the thin flange. That is, though the thin flange has partially cooled, it is prevented from getting quite set by the heat which is transmitted to it through the stout web, which again receives accessions of heat from the thicker flange. A glance at Fig. 8, No. 2, will show the reason. Down to about the plane a a, cooling down goes on rapidly; but beyond that the portions B continue to supply fresh accessions of heat to A. And so it happens that the shrinkage of A is delayed until at last it sets sufficiently rigid to prevent B curving to any great extent. If the web is very thin, as in Fig. 8, Nos. 3 and 4, the transmission of heat will soon cease, the crystals will set, and the result will be that the thick flange will assume a considerable amount of curve; but the mass in the thick web, Fig. 8, No. 2, lessens this by delaying the cooling in the thinner flange, the crystals in which are thus enabled to accommodate themselves slowly to the state which exists in the hotter sections—in other words, they become larger and more open than they would if allowed to cool quickly. Again, if a web is of considerable width, it resists the curving of the thick flange just as the wide web does in Fig. 6. It is from these various causes that the amount of camber which the patternmaker has to impart to girders differently proportioned is so uncertain.

A class of castings of another kind, copings, or sills, afford a contrast to the girders. A plain right-angled piece, Fig. 9, will have both sides curved slightly, so that the dotted line would represent the plane of the maximum curvature. A section like Fig. 10 will go hollow at A, or will remain straight, depending entirely on the thickness there. If A is thicker than BB, A will curve; if a little thinner, the casting will remain straight. A casting like Fig. 11 will curve along the edge A, but it will remain practically true, even though one flange is deeper than the other, provided flange B is increased sufficiently in thickness to counteract the pull of A. In these cases the castings remain as they first shrink, setting rigidly, and retaining permanently the form in which they set, differing in this respect from the girders, Fig. 8.

An engine bed like Fig. 12 is an object somewhat like a double girder in section, and such beds of certain proportions go concave along the top edge in cooling, due to the extra metal of the web there. On



FIG. 1.



FIG. 5.

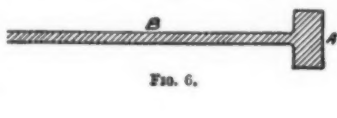


FIG. 6.

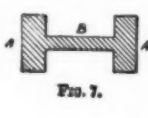


FIG. 7.

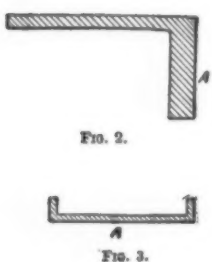


FIG. 2.

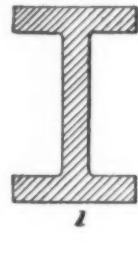


FIG. 3.

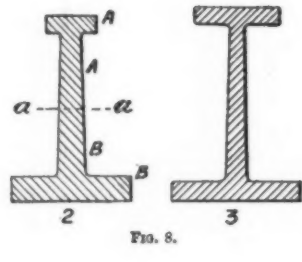


FIG. 8.



FIG. 4.

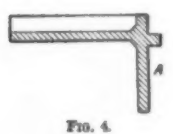


FIG. 9.



FIG. 10.

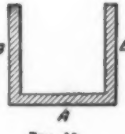


FIG. 11.

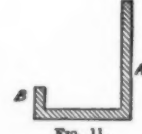


FIG. 12.



FIG. 13.

first thoughts, one would expect the filleted bottom edges to go concave; but this is not the case, because, though the fillets are heavier than the webs, the plate A has more mass than these, and, therefore, continuing to shrink after these, takes on a curvature. Heavy fillets, however, lessen curvature.

A common gutter, Figs. 13 and 14, is another familiar example. Here A continues to cool after the thin edges, B, have become set, and so the bottom inside of the gutter invariably becomes convex.

A common buckled plate becomes slightly convex along the flat or flanged face when cooled, because the plated mass around the buckled part continues to shrink after the face has set rigidly. An example of a kindred kind is the penstock door shown in cross-section in Fig. 15. These doors, of about 7 feet in length, and cast $\frac{3}{4}$ inch thick only, showed a convexity of $\frac{1}{2}$ inch in their length, due to the pull of the shrinking metal around the buckled portion. We had some trouble with these, for after the pattern was curved the casting remained curved.

But thin and shallow plated castings are always very sensitive to cooling stresses, especially if they are uncovered before they have quite set. And if a plate begins to go in one direction it gets into a condition of buckle, and will continue to go in that direction, up or down, in which it has started. Large flat plates are weak, due to the internal tensions set up. A buckled plate is strong, partly because of the buckling, but partly also, because the plate has not shrunk on itself, but the buckle has taken up some of the shrinkage. Plain plates, therefore, seldom come out of the sand true. If a plain plate is cast in open sand, it will curve upward at the corners in cooling, becoming concave on the top face, because the heat is more rapidly dissipated from the top face than from the bottom. If it is covered over, it will more often come out true; but this depends on the thickness of sand in the cope. A shallow rib cast round helps to keep plated patterns true. Thus flanged tank plates seldom show as much as $\frac{1}{4}$ inch of concavity on the back.

Familiar examples of curving are found in pipes and columns cast on their sides, i.e., not upright. If a core, insufficiently chapleted, is borne upward by the pressure of metal, making the top metal thin, and the bottom thick, Fig. 16, the pipe or column will become

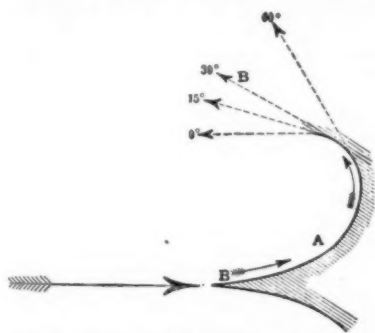


FIG. 1.—SINGLE-STAGE TURBINES.

concave on the top face. This is directly opposite to that which we observed in the girders. The reason is that the castings are comparatively light, and therefore no important transmission of heat can take place between the thicker and thinner parts, such as takes place in stout girders, and the thick side is therefore cooled by the thinner one, which first sets. A similar result follows if the top of a pipe mold is uncovered; the top side cooling will pull the rest with it, making a concave pipe. If a flat plate is uncovered while red hot it will also curve upward, following the face which cools off first. Sometimes columns are cast with the metal thicker on the top, where it is liable to be spongy, than on the bottom. This is liable to produce curvature in the downward direction, unless the precaution is taken of uncovering the top to hasten the cooling there.

The problem of how to prevent curving is one that often presents itself to the patternmaker and molder. Besides the ordinary precautions taken by the molder, patterns are in many cases curved in the opposite directions to the camber, and to the amount by which the casting is expected to curve. This is easily done in heavy patterns like girders; but the patterns of light gutters, and those of plates, must be rammed on a bottom-board, to which the proper amount of curve is imparted. The patterns, though also made to the suitable curves, would become rammed out of truth unless this precaution were taken.—English Mechanic and World of Science.

SIMPLE STEAM TURBINE ENGINES.—I.*

By JOHN RICHARDS.

I SHOULD perhaps apologize for presenting before the society a paper of so elementary a nature as the one that follows; but it may be assumed that such papers are directed to two objects—the advancement of technical knowledge among the members and the furnishing of popular information on technical subjects. The present paper belongs mainly in the second category. It is devoted to a subject so new at this time, in a popular way at least, that its elementary character will be an advantage, especially as the scientific phase of the subject has had copious treatment at the hands of others.

* Read before the Technical Society of the Pacific Coast.

It is a strange fact that the "evolution" of steam turbines is following a course quite the opposite of that of piston engines. In the latter the constructive part was developed and in a great measure completed before the thermal or thermodynamic features were investigated and explained; and, as a matter of fact, ignoring the modern demands of increased speed and pressure, the constructive feature of such machines has not greatly advanced in recent times.

Some of Watt's steam engines remained in constant use for a century, and many old engines made in this country had a record of fifty years and more; but, as

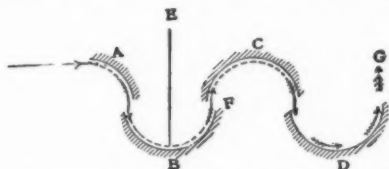


FIG. 2.—MULTIPLE-STAGE TURBINE.

remarked, the thermal or thermodynamic features that pertain to the art have only in recent times become understood and applied. Thirty years past will include what may be called the scientific evolution of piston or pressure steam engines, and, with some exceptions, will include the development of their proportions and their arrangement into types.

In steam turbines the scientific part has preceded the constructive one; in fact, was complete in essential points when their practical construction and use began. This was, of course, because all steam and heat engines are governed by the same general laws, with the difference that turbine or impulsive engines deal with the flow and gravity of steam instead of its pressure, and hence are more complicated in several respects, but, as before remarked, they follow certain ascertained laws which govern heat engines in general.

The problem of constructing turbine engines has, as may be claimed, only begun. Even the types are

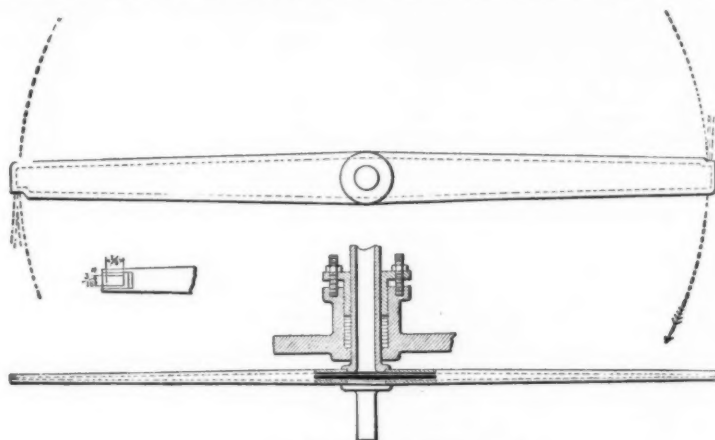


FIG. 4.—THE AVERY TURBINE.

not yet determined, and no doubt many years will elapse before this branch can reach a successful evolution and constant types appear. Design and methods of construction must arise out of use and experience, and must be proved by the inexorable tests of efficiency, endurance, adaptation, economy, and cost.

A principal fact relating to turbine engines now in use is that while this term is applied to all kinds of steam wheels driven by impact, reaction, or pressure of steam there are two types that are quite distinct as articles of manufacture. One of these types I will call "single" acting, the other "stage" acting. These types are best known in common speech by the names of inventors who have in recent times been most prominent in their development; the single-acting as the De Laval or Riedler type, the stage or double-acting as the Parsons type. Another type, that will have some

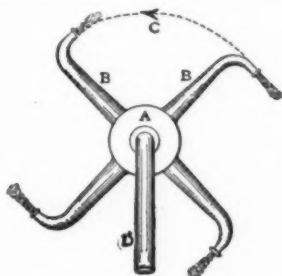


FIG. 3.—HERO'S TURBINE.

notice hereafter, is the reaction type, not commercially made at this time, but a "parent" of the whole, as will appear.

The two first-named types of engines are also designated as impulse and pressure machines, but these terms do not very clearly define just what is meant; they are, however, as nearly descriptive as any that can be selected for the purpose. The action to be described in these cases will be better understood by saying that one operates by "push" and the other by

"blows." One is free running or open, the other inclosed to maintain pressure.

Of steam turbines, those of the stage or Parsons type are at this time the most numerous and the best known, and they have engrossed the thought and skill of many able engineers. They correspond in many respects to inclosed or pressure water turbines of the Jonval, Fourneyron and centripetal types, which act mainly by "push" or pressure, but not by sustained pressure in the same way as in the action of pistons.

The stage or successive action of the steam in this type of engines has for its main object the reduction of speed and rate of revolution, thereby adapting the machines for coupling directly to pumps, dynamos, marine screws, and so on. It also avoids the enormous centrifugal strain set up in single-action machines.

Turbines of the single-action or impulsive type are open and without maintained pressure, as in the tangential, Girard, and other unfilled water wheels. Consequently they have no running joints to maintain against steam pressure.

Steam and water turbines being analogous in many of their features, and the latter being much better understood, especially on this coast, where water turbines of all kinds are employed, a comparison will aid in the present explanation.

The main distinction between steam and water turbines arises out of the different natures of the two fluids. One is elastic and light, the other inelastic and heavy. In the case of water the velocity of efflux is low and in proportion to its density, reaching a velocity of about 80 feet per second under a head of 100 feet, or a pressure of 43 pounds per square inch; but in steam the velocity is immensely greater. The velocity, in feet per second, of efflux from nozzles equals 60 times temperature in degrees Fahrenheit plus 460. This gives a velocity of 1,680 feet per second for steam at a pressure of 100 pounds per inch; but this is much less than is now assigned for actual efflux from nozzles on which the speed of turbines must be computed. The practical velocity of turbine wheels is computed on a flow of 3,000 to 4,000 feet per second, and for the vanes from 1,200 to 1,500 feet per second,

or 75,000 to 100,000 feet per minute. This is more than twelve times the rate of the fastest railway trains, and, as a physical fact, almost evades the power of conception.

Otherwise than as to the great difference in their velocity, steam and water turbines follow like laws; the spouting energy, as it is called, being theoretically equal to the gravity; or, in other words, the "blow" is equal to the "push," provided the kinetic energy of the impact or blow can be equally utilized.

The action of all unconfined liquids is expressed in an old rule (it may even be called a gospel) of fluid motors: The fluid must "enter without shock and leave without velocity." This rule, applied to any motor driven by the impulsive energy of a fluid, will determine the correctness of the machine's operation, or, as it is called, its efficiency, meaning the useful effect produced in proportion to the weight and velocity of the fluid consumed.

To further explain this action of fluids, if a stream is directed against a fixed flat surface, only a portion of the energy is imparted to the surface; about one-half, in fact. The entry is a shock, and the fluid is scattered in a lateral direction with violence and leaves with velocity. If the same stream of fluid is directed tangentially into a curved vane or bucket, as in Fig. 1, and if its course is gradually reversed, it will leave with velocity, and that much of its energy will be lost; but if the bucket or vane, A, is set in motion with the fluid at one-half its velocity, then, by the component of these motions, the fluid will be brought to a state of rest, and will leave without velocity, the buckets receiving the total energy less fluid friction and some loss due to the divergence of the lines B. This is the manner of operating in all fluid motors of the impulse type or of single action.

The tangential entrance of the jet or stream and the resultant or discharge angle are very important features in practice, and will be again considered at some length, not in respect to economy alone, but as materially modifying construction in several ways.

Reverting now to the filled or pressure class of turbines for water or steam, these operate in a different manner, by what is commonly called pressure, but not

pressure within the usual meaning of this term. "Obstructed flow" comes nearer describing the operation.

The course of the fluid through the machines is made so tortuous or difficult, by means of reversing or baffling curves or vanes, that the gravity or pressure of the fluid acts like a static force.

Fig. 2 illustrates, in an imperfect way, this action, the large arrow, in this as in other diagrams, being employed to show the line of impingement or course of the fluid.

If all the vanes or buckets, *A*, *B*, and *C*, were fixed, it is clear that the water would be discharged at *G* with reduced velocity, even if it were confined; but if the vanes, *B*, are set in revolution in the plane at *E* at half the velocity of the water, it will be left at *F* in a state of rest or without velocity. If the vanes, *B*, are set in revolution at one-fourth the velocity of the water, there will be a residual discharge of force at *F*, to enter the third set of vanes, *C*, these latter revolving in an opposite direction, so the speed of rotation of any set of moving vanes will be reduced accordingly. If the vanes, *C*, are fixed, and discharge into a fourth set of vanes, *D*, the rate of rotation can be reduced again as the square root of the water's velocity in the two cases. This is the manner in which the speed of stage turbines is reduced.

The vanes *A* and *B* may represent a common water turbine. With the vanes *C* fixed and those at *B* and *D* moving, we have a two-stage steam turbine, except that in all cases the buckets or vanes, whether for steam or water, are of ellipsoidal or other modified curves.

Water turbines of this class have commonly only two sets of buckets or vanes—*A* and *B*, for example—one fixed and the other movable. Stage steam turbines have from five to ten sets of vanes, the mobility of the fluid demanding this difference. All motors of this class are called "filled," the induction and ejection passages being approximately of the same size in the case of water wheels, but increased, of course, for elastic fluids to accommodate their expanded volume.

One other class of motors remains to be noticed, viz., the reaction type. Their manner of operating will be more clearly explained later on.

These remarks will, I hope, explain the classes or types of steam-turbine motors as now made and in course of evolution; and, with this much respecting the principle or mode of their operation, I will turn briefly to their history and afterward discuss the constructive problems, which, as at first explained, form the principal theme to be dealt with at this time.

It is common to begin the history of steam engines with an account of the "æolipile," made in Egypt about two thousand years ago, by Hero, a Roman architect. This device, with which almost every one is familiar, is illustrated by Fig. 3.

It is an organized steam motor, much better than some made at this day; and, considering the circumstances of the time, was a wonderful production, evincing, as it does, a knowledge of the expansive force of steam; also the principle of reaction. *A* is a rotative steam-containing vessel, *BB* are hollow arms delivering jets of steam tangential to the path of revolution, *C*. Supposing the vessel, *A*, to be filled with steam from a pipe, *D*, at a pressure of 100 pounds per square inch and the area of each jet to be 0.1 inch, or together 0.4 inch, then the pressure on these orifices, if closed, would be 40 pounds. When open, there is no pressure on this area, but an unbalanced back pressure of 40 pounds in the opposite direction, the turning force, due to reaction or unbalanced pressure.

I am aware that a mathematical treatment of this matter would involve the ponderable matter discharged, its velocity, and other intricate conditions; but the theory of unbalanced pressure will answer for present explanation.

This Hero wheel was a reaction turbine, and, as such, was a much more complicated and ingenious conception than the direct-acting or impulsive wheel of Branca, which followed in 1629, about eight hundred years after Hero's æolipile.

This latter device can scarcely be considered an invention; but it must be remembered that the expansive force of steam was, even at that date, a mystery. No useful application of this device is known, and it was only a toy, consisting of a wheel with flat vanes against which a jet of steam impinged.

From this point the art seems confined to England, or mainly so, and from 1784 to 1901 there were granted in that country more than four hundred patents for machines that may be classed as, or with, steam turbines. These various patents have been recently examined and listed by Robert M. Neilson, an engineer of Manchester, England, who has arranged a chronological list of them in a treatise on "Steam Turbines," published last year.

Even James Watt, John Ericsson, Perkins, and other well-known steam engineers "had a try" at these obdurate machines without permanent result, and an inference, to be drawn from the copious array of schemes proposed, is that the principal impediments were in various operating conditions now better understood and mainly the want of resources for constructing machines to move at such great velocity.

There is also the fact that, in so far as principles or modes of operating are concerned, these inventors anticipated about all that is known in the present steam-turbine practice, except in the respects just named.

Kempein's engine of 1774 was a reaction one, with the arms and vents as in the æolipile of Hero. James Watt's machine of 1784 was similar in operation, with this difference, that he proposed to vent the steam un-

der mercury or other fluid. Sadler, in 1791, devised a compound machine or one of double action, also of the reaction type. Trevethick, in 1819, proposed a reaction machine, and John Ericsson, in 1830, patented a very well designed reaction wheel.

In 1843 Pilbrow patented a stage turbine with a large number of fixed and moving vanes or buckets arranged for expansion. Indeed, his machine had all the main features of modern engines of the stage type.

In 1848 Robert Wilson patented the first radial-flow steam turbine, which in design fully anticipates the Dow and other radial-flow machines of our time. He also proposed a parallel-flow engine with expanding chambers or spaces, in the manner of Parsons.

In 1888 Alexander Morton, a well-known engineer of Glasgow, Scotland, made experiments with a steam turbine of ingenious form, and other inventors in Scotland made reaction machines that were said to be applied to practical work; but undoubtedly the principal part of the history of reaction engines was the invention of William Avery, of western New York, who, about 1825, made and put in successful operation a large number of such engines.

Mr. Avery was a near relative of Prof. John E. Sweet, president of the Straight Line Engine Company, of Syracuse, N. Y., to whom I applied some time ago for information respecting the Avery engines. Prof. Sweet replied as follows:

"In respect to the history of the Avery engines, these were made seventy-five to eighty years ago by William Avery, a local mechanic here. There were about fifty constructed and put in use. One of the runners is now in my possession; another, that I saw years ago, had a hollow shaft of perhaps 1½-inch bore. The head or runner was of sword shape, the arm 1 x 3 inches at the center and ¾ x 3½ inches at the ends, the diameter swept being about 5 feet. Steam was admitted through the shaft by means of a stuffing-box, passed through the shaft to the hollow arms, and escaped at a tangential issue ¼ x ¼ inch, at the rear corners of each arm, the ends of which were stopped by plugs brazed in. Owing to the rapid rotation of the arms—10 to 15 miles per minute—the front edges were so rapidly cut away that replaceable blades made of tempered steel were inserted so they could be renewed. The fact that the engines had to be taken to a blacksmith shop every three or four months for renewal or repairs had more to do with their abandonment than their lack of economy. As to the latter, people who knew the facts, or claimed to do so, said that when they changed to the common slide-valve engines there was no gain in steam economy over the Avery engine.

"Another feature that worked against the Avery engine was the stuffing-box around the shaft, which, in the hands of workmen of that time, was apt to be set up so as to consume a large part of the power in friction. This was a natural consequence, as the wear was rapid. What the result would have been with a truly ground shaft in a metal bush, instead of a turned shaft and stuffing-box, making the issues expanding nozzles and multiple expanding by two or three arms in separate cases and connecting to a condenser, is not known. It might rival a pretty good modern engine, if not the best.

"The Avery engines were used in sawmills and wood-working shops of the time. They had weak starting power, and did not need much for the uses named. They ran at such a fearful speed that the reducing motion was an impediment. Mr. Avery had to employ bands, which were far more objectionable than gear wheels.

"The Ruthven and also the Gorman engines of the same type are mentioned by Prof. Rankine in some of his writings and claimed as attaining an economy equal to piston engines of the time."

Prof. Sweet sends, with his communication, a drawing of the Avery impeller in his possession. This is shown in Fig. 4, and it must be admitted that the circumstances described, as before remarked, form a principal fact in the history of free-running engines. The economy attained, even if there were no other fact than that of fifty or more engines being made and put into practical use, is enough to amaze one when it is considered that the engines were purely reactive, like a Barker water wheel or the Hero engine in Fig. 3, and that the inert fluid under atmospheric pressure was left directly in the path of the impeller's arms, and wore away the front part where the pieces were inserted. The casing was no doubt of a form to prevent free revolution of the spent steam, otherwise this impediment would to a great extent have been avoided.

This machine admits of further comment, especially in its constructive features, and I have no hesitation in claiming that the material is in this case better disposed to resist centrifugal strain than in any steam turbine now being made. The speed was no doubt equal to that of machines now constructed. The structure is not exposed to incomputable inherent strains, as continuous wheels or disks must be, and the box section, made of thin metal plates, is the strongest known in the arts.

In a letter received from Charles Brown, of Basel, in 1903, I find the following remarks respecting the Avery engine:

"Early in the forties an American engineer of the name of Pratt told me that he had experimented with two of Avery's Hero reaction wheels, one with 100 pounds steam running at 45,000 feet per minute. It gave 30.3 horse-power and consumed 7½ pounds per horse-power hour, and another with 130 pounds steam giving 24½ horse-power consumed 6.16 pounds running at 54,000 feet. Diameter at nozzles, 5 feet. If

these data are correct the result compares well with a 30-horse-power Laval, which, non-condensing, consumes fully as much coal as the old Avery. Pratt told me that Avery had built a locomotive with his wheel, Avery's engine had the advantage over the Laval that the number of revolutions, 2,800 to 3,600 per minute, are so low that it might be used for driving many machines without the intervention of gearing, so that it might be worth while to take up the study of the Avery again, for the wear and tear of the Laval gearings is heavy. For heavy work, the Parsons is not likely to be superseded for some time yet, Brown, Bouverie & Co. are crowded with orders, and the works are in a chronic state of expansion; the large sizes are so much more economical that the piston people have no chance. Latest tests gives 8 pounds per indicated horse-power hour."

The next step in practically applying the free-running steam wheel to useful purposes was, so far as I know, by Dr. De Laval, of Stockholm, Sweden. I was often in Sweden during the earlier experiments there, and imbibed a curiosity and interest in this matter that has lasted ever since, especially since coming in contact with the tangential type of water wheels on this coast. These latter are operated under pressures much greater than has been attempted with steam motors; that is, up to 900 pounds per inch, giving a velocity of 120 feet per second. I believe, and I shall attempt to show, that such wheels are made on a system much in advance of steam-turbine practice in some very important respects.

Following Dr. De Laval and perhaps others in steam-turbine wheels of single action, came a successful division into stages by Hon. C. A. Parsons, one of the most eminent steam engineers of our time. This subdivision, it may be called, of the steam turbines, had for a principal object, as before pointed out, a reduction of the speed of wheels and their adaptation to direct driving of dynamos, marine pumps, screws, and the like, offering uniform resistance or load.

Wheels or engines of this type involve the maintenance of running steam joints between the stages, and demand workmanship that is now and will likely remain a bar to their general manufacture. There is also an inability to endure lateral stress on the spindles, because the running steam joints that separate the stages of pressure have a clearance of about 0.01 inch. These latter features have confined the engines to purposes where simple torque is delivered, but this includes a great part of the whole field of motive power.

Parsons's modification of these engines has called out scores of inventors and imitators in this and other countries, and it seemed for a time as though the De Laval engines were to remain sole representatives of the single-action system; but a reaction has begun, most notably in Germany, where Prof. Riedler, the author of "Indikator Versuche auf Pumpen" and much other noted work, has, in conjunction with Prof. Stumpf, produced single-action engines up to 2,000 horse-power, apparently of durable but expensive construction. I have drawings of these engines, accompanied by German text, with a list of engines in operation up to November of 1903.

There have been scores of abortive attempts in single-action machines, and no doubt there will be many more, because the problem, as a constructive one, offers a fertile field for the contriver incapable of understanding the impediments to be overcome.

The mechanical construction of machines should be approached by analysis of their operating conditions.

These latter are not amenable to computation, except a few, such as the strength of material, normal strains, endurance, or wear, and so on; but beyond these things lie what may be called the "phenomena of operation," that must be learned by observation, inference, analogy, and, for the most part, empirically.

To illustrate what I mean: The generation of electric current by dynamos was a well-founded science long before there were durable and reliable journal bearings for the armature spindles, and these are now a survival from endless modification. The commercial factors of symmetry, cost, endurance, and many other qualities belong in the same category and are not computable.

(To be continued.)

THE WORK AT PANAMA.*

By THEODORE P. SHONTS

I PROPOSE to talk as a practical man to practical men who are themselves engaged in large commercial enterprises, and who know from experience the difficulties to be met and the enormous amount of thought and labor involved in the inauguration of great undertakings in the United States. You will be able to appreciate, therefore, how every difficulty was aggravated in an enterprise of the magnitude of the Isthmian Canal, in which the preparatory work had to be carried on two thousand miles from the base of supplies. But this is not all: The work had to be done in a hostile climate and under health conditions which, through centuries of neglect of all sanitary principles, had become a menace to the lives of all persons save natives of the tropics.

In order, therefore, to make the Isthmus a place fit to live in and to work in, there were three fundamental tasks which had to be performed in advance of all others.

First. Thorough sanitation of the Isthmus.

* Extracts from an address before the American Hardware Manufacturers' Association, at Washington, November 9.

Second. Providing suitable habitations for all classes of employees.

Third. Providing a system of food supply which would afford to all employees opportunity of obtaining wholesome food at reasonable cost.

1st. In regard to sanitation: When the United States began this work there were no systems of water-works, of sewerage, or of drainage on the Isthmus. The people depended largely on unprotected cisterns for their water supply, filled during the rainy season, and on barrels filled from neighboring streams, all breeding places for mosquitoes. The filth of ages had accumulated around the dwellings and in the streets, undisturbed except when washed away by torrential rains. Pools of stagnant water had existed for years in proximity to dwellings and insect-breeding swamps lay undrained adjacent to the cities and many of the towns. Seventy per cent of Panama is now supplied with pure mountain water, fed from a storage large enough to furnish sixty gallons per day to each inhabitant after its present population shall have increased one-half. Fifty per cent of a complete modern sewerage system has been installed, and work on the remainder is being carried rapidly forward. The first million of brick for paving its streets are on the ground. The city has been fumigated time and again, first house by house, to stop the spread of disease, and again as a unit, that is, the entire city at one time. A large force is just finishing a thorough cleaning of the city—the first scrubbing it has had during its centuries of existence; and Gov. Magoon, under whose jurisdiction all this work has been accomplished, is arranging to raze many of the worst shacks and replace them with modern, sanitary buildings. Within a year, it may confidently be predicted, Panama will be a city well watered, well sewered, well paved and clean and healthy.

What has been done for Panama is being done for Colon and every important labor camp across the Isthmus. Work on Colon's water reservoir is well under way and temporary measures are being employed to safeguard the city's health pending the report of a board appointed to recommend plans for permanent improvements. An abundant supply of pure water from mountain springs has been provided at Culebra and at other important labor centers along the line of the canal, and adequate drainage is being installed in them also.

In these sanitary undertakings 4,100 men are now employed. So effective has been the work that yellow fever has been virtually extirpated from the Isthmus. In June last there were 62 cases of yellow fever there; in July, 42; in August, 27; in September, 6, and in October, the worst month of the year for yellow fever, 3—no one of the latter among the employees, and all originating many miles from the line of the canal. In regard to general health conditions, I was told, when on the Isthmus in October, that there were over a hundred less patients in Ancon Hospital than there had been for many months, although we had brought in 4,000 additional laborers during the previous two months, and it was from the new arrivals that the hospitals were usually recruited.

To fully understand what has been accomplished by our sanitary work it is only necessary to compare the present rate of sickness with that which prevailed on the Isthmus when the French were in possession. In August, 1882, the second year of the French occupancy, with a force of 1,900 men, the death rate was 112 per 1,000. In August, 1905, with a force of 12,000 men, there were only 8 deaths, or two-thirds of a man per 1,000.

We have established a hospital system which includes a large hospital at Colon and another at Ancon, and a number of smaller hospitals at convenient points along the line. The one at Colon is built on piers over the Atlantic Ocean, and patients there have at all times the benefit of cool and invigorating sea air. That at Ancon is one of the largest and best equipped in the world, situated on the hill above Panama and commanding a superb view of mountain and sea.

The management and service of the hospitals are on a par with the natural advantages and beauty of location. Col. Gorgas, who is in direct charge of hospitals, has organized a staff of doctors and nurses for which it would be difficult to find a superior anywhere. Mr. Isham Randolph, one of the members of the Consulting Board of Engineers who recently visited the Isthmus, said, in a letter published on his return: "The hospitals are a source of just pride to our people. If sickness could ever be regarded as a boon, it may be so thought of in Ancon and Colon."

2d. In regard to providing quarters for the employees. The commission inherited from the French Company more than 2,100 buildings, all in bad condition. During the past year, 649 of them have been repaired, 58 new buildings have been erected, and 67 more are in course of construction; two new hotels, three stories high and containing from 55 to 60 rooms each, have been completed, and authority has been granted for eight others, a portion of which are under construction at the present time. Work is in progress also on cottages for married employees and on bachelor quarters. In this work of construction 2,400 men are employed, and additional carpenters are being sent out with every steamer. This work is being pressed forward with the utmost vigor.

3d. In regard to food supplies. This was the most serious problem that confronted us. If we couldn't feed the men, we couldn't build the canal. Owing to the fact that the natives never look beyond their present necessities, no surplus food supply ever accumulates. This normal condition of no surplus was greatly intensified by the almost total failure of the crops for the two preceding years, by the abandonment by agri-

cultural laborers of their farms back in the hills for work on the canal, where they received higher pay for shorter hours, and by quarantine against the port of Panama on account of bubonic plague, which prevented the arrival of food stuff from neighboring provinces.

We were thus brought face to face with the problem of feeding 12,000 men, with base of supplies 2,000 miles away.

We immediately arranged to open local commissary stores at every important labor camp, to provide mess houses, and to furnish food, both cooked and uncooked, to all employees at cost. We cabled orders to have our steamers equipped with refrigerating plants; we arranged for the erection of a temporary cold storage plant at Colon; and we purchased refrigerator cars for immediate shipment to the Isthmus, thus establishing a line of refrigeration from the markets of the United States to the commissary stations of the Isthmus. We also purchased from individual lessees the equipment in existing hotels and assumed their management ourselves. The net result of these efforts is that to-day we are affording to all employees opportunity to obtain an abundant supply of wholesome food, cooked and uncooked, at reasonable prices. The silver men—by which I mean the common laborers—are being fed for 30 cents per day, and the gold employees—by which I mean those of the higher class—at 90 cents per day, and it is good food in place of bad.

The only really valuable instrument essential to canal building acquired by our government in its purchase from the French was the Panama Railroad. But this instrument, like all the others whose wrecks cover the Isthmus, had been neglected and its equipment allowed to become obsolete. If the docks, wharves, warehouses, terminal yards, locomotives and cars of the Panama Railroad had been in good repair, which they were not, they still would have been entirely inadequate to properly care for and handle the small commercial business the road was transacting. The existing facilities, poor as they were, were rendered less efficient by the entire absence of any mechanical appliances on the docks to assist in receiving or discharging the steamers' cargoes. The negro laborer was the only power employed; he was at once the only hoisting machine and the only traveling crane in use. Imagine, then, the congestion which necessarily ensued when the accumulated orders in the States began to arrive in large quantities on both sides of the Isthmus. To aggravate the situation, while the deluge of arriving material was at its height, the commercial business of the road increased nearly 50 per cent over the year before; and at the moment when we thought affairs could get no worse, two cases of bubonic plague at La Boca resulted in two consecutive quarantines at that place, completely tying up that outlet for 60 days. Furthermore, the personnel of the Panama Railroad as acquired had not been educated on modern lines, and therefore was completely paralyzed when confronted with the onerous conditions caused by this congestion. It was necessary, consequently, to begin at once the construction of new wharves equipped with modern mechanical appliances, and of large terminal yards at both ends of the road; of extensive warehouses; of suitable machine shops, and of a modern coal hoisting plant, which will reduce the cost of handling coal from ship to engines from \$1.30 to about 12 cents per ton.

We have also purchased new and more powerful locomotives, larger cars for both passenger and freight services, and heavy steel rails for relaying the road, and have strengthened the bridges to enable them to carry the heavier equipment. We have reorganized the personnel of the road, putting into the higher positions experienced, aggressive, up-to-date men, with the result that with the old equipment and facilities they have cleared up during the last thirty days an accumulation of over 12,000 tons of commercial freight. With the advent of our increased dock facilities, terminal yards now nearly complete, and new power and equipment now arriving, the road will be in a position to handle efficiently and economically a vastly larger volume of business than heretofore.

While all this necessary work was in progress, the task of purchasing, forwarding, and distributing the enormous quantity of materials and supplies of all kinds was receiving our constant and most careful attention. The purchases included not only the items entering into the permanent plant, but also those required for the preliminary work. The approximate total cost of our purchases was about \$9,000,000.

It should be borne in mind that at the time when orders for most of these items were placed, the industries of the United States were crowded with domestic business, and were unable, consequently, to make prompt deliveries. It should be borne in mind, also, that after machinery had been manufactured here and set up, it had to be taken apart, shipped 2,000 miles over steamship lines already taxed to their full capacity, and on arrival on the Isthmus had to be again set up before ready for use. Then, too, on account of many reports as to the prevalence of yellow fever on the Isthmus, it was very difficult at a critical time for concerns furnishing material to get steamers to take it there, because of fear that their crews might become infected and their vessels might be quarantined when they wished to return to the United States. Finally, the steamers of the United Fruit Line from New Orleans, which had been carrying a considerable amount of the freight going to the Isthmus, were put out of service on account of yellow fever in that city.

To the various causes of delay mentioned is to be added the requirements of law that all bids for materials used in government work shall be advertised for. This compels a delay in all cases of from ten to thirty days.

Furthermore, in addition to the purchases for the canal, the following have been ordered for the Panama Railroad: 500 40-ton box cars, 12 caboose cars, 10 refrigerator cars, 6 passenger coaches, 24 locomotives, 2 wrecking cranes, 1 locomotive crane, 1 pile driver, 3 100-ton track scales, 1 modern coal hoisting plant, 1 cantilever crane coal hoisting plant.

In regard to all equipment purchases, both for the canal and the railroad, it should be stated that the gage of the Panama Railroad being wider than the standard gage in the United States makes it impossible to use second-hand rolling stock of any kind; all locomotives and cars had, therefore, to be built to order. The elimination of yellow fever and the establishment of better systems of housing and feeding the employees have enabled us to recruit our working forces till those assigned to the material and supply division now number over 2,100 men.

I have so far endeavored to give you an idea of the difficulties which we have had to encounter and overcome in order to make the Isthmus a place fit to work in, and to collect the tools with which to work. So far as actual excavation and dredging are concerned, we have not endeavored to accomplish much. As a general principle, in which I think you will all concur, it is inadvisable to attempt to run a railroad before the tracks are laid. We are now working, however, six steam shovels in Culebra cut, which is the largest single factor in the construction of the canal, and have removed approximately one million cubic yards of material. By this work we are accomplishing two things: First, we are putting the levels of the cut in proper condition for the installation of the largest number of machines which can be effectively operated; and, second, we are gathering data which will be useful in future estimates of the cost of canal construction. In the Culebra work 2,600 men are now employed. We are also building railway tracks and yards, and are dredging at both ends of the canal, so far as advisable until the question of type of canal is decided. It should be understood that all the work we have done is applicable to any type of canal.

The question of labor is a grave and perplexing one. We have advanced far enough to know that we can secure a sufficient supply of labor from the tropics, so far as numbers are concerned. The question of quality is a very different matter. Unless a much greater efficiency can be developed than is secured at present, we shall have to look elsewhere.

To these tropical laborers we are paying from 80 to 90 cents per day in gold, and it is estimated that we do not get more than 25 per cent of the efficiency of labor in the United States. This is the kind of labor to which we are compelled to apply the eight-hour law—that is, to aliens who know nothing of the law's existence until they arrive on the Isthmus. Such application will increase the labor cost of canal construction at least 25 per cent, and will add many unnecessary millions to the total expenditure.

In my opinion it is a mistake to handicap the construction of the Panama Canal by any laws save those of police and sanitation. I want to go on record here that the application of the eight-hour law, of the contract labor law, of the Chinese exclusion act, or of any other law, passed, or to be passed, by Congress for the benefit of American labor at home, to labor on the Isthmus, is a serious error. Over 80 per cent of the employees of the canal will be aliens. A majority of the other 20 per cent employed will be in a clerical or supervisory capacity. The application of these laws on the Isthmus will benefit a very small number of American laborers but will enormously add to the cost of construction, and American labor at home will have to pay its share of the consequent increase in taxation.

In line with this, let me add that Chief Engineer Stevens is preparing three complete sets of plans applicable to as many types of canal, so that when decision shall have been reached as to what type will be used, no delay in beginning work will ensue. It is our confident belief that by the first of July next the plant as purchased will be installed and working to its fullest practical capacity. In other words, by that time the dirt will begin to fly in earnest.

The canal will be built—rest assured of that—and it will be built at Panama. Those two phases of the problem have passed irrevocably from the field of debate.

There is an industrious and voluble band of hired Ananias moving to and fro in the land whose mission it is to deny this. Who is capitalizing this industry? What is the bountiful source of this spouting spring of mendacity? What interests, except those foolishly dreading the competition of an Isthmian Canal, would put up money to delay and possibly defeat its construction? That there are interests of that kind is not a matter of suspicion or speculation, but of history. They have been fighting a canal for more than half a century, and they fought it successfully till Theodore Roosevelt, armed with his "big stick," appeared as its champion. Behind Theodore Roosevelt stand the American people in solid mass and with determined front, shouting as one man: "Give us a canal that will be adequate to meet the demands of the commerce of the world, and give it to us at the earliest possible moment." That, gentlemen, is the command which the Commission, under the inspiring lead of the President, is obeying to the letter.

Owing to the impossibility of repairing the Canary Islands submarine cable, the Spanish Minister of the Interior is in favor of laying a new cable between Spain and the Canaries, and another to the north of Africa.

THE DOMESTIC LIFE OF ANIMALS.

By DR. TH. ZELL.

ONLY to a limited degree may animals be said to enjoy domestic life. This fact is due to various circumstances, among which the following may be mentioned:

The care taken of young offspring is proportionate to their helplessness and the time occupied in attaining maturity. From this standpoint let us compare man with any of his domestic animals. In from one to two years the dog attains full size, and even so large a species as the bovine becomes capable of reproduction. The hatching chick breaks its own shell and at once stands on its feet and begins to hunt for food. Wild animals are still more precocious. A wild gosling a few days old can outrun a man. In comparison with such examples how helpless a creature is a newborn infant! This striking contrast was noticed by the ancients. Pliny says: "Other creatures feel their strength at once, and run, fly, or swim; but man comes from the hand of nature able only to cry. Everything else, speaking, walking, eating, etc., must be hardly learned under the spur of necessity." Therefore human family life must be the most perfect and intimate, if only for the reason that a child is the most helpless of creatures and requires nearly two decades for its development into a man or woman.

Another consideration is this: True family life, in the strictest sense of the term, implies the participation of the father in the care of the offspring. Now, it is a remarkable fact that the animal kingdom contains a great many bad fathers as well as countless good ones. Among all classes of birds good fathers are the rule and bad fathers the exception, but among mammals the reverse is the case.

These facts are closely connected with another. Polygamy is by no means uncommon in the animal kingdom. Now it is obvious that no polygamous male will bestow as much care on his offspring as the best of monogamous fathers.

Notwithstanding these great differences between man and other animals, their behavior in regard to family life agrees in many points. One reason why this fact is not generally known is that the most touching traits of the family affection of animals have been observed in distant lands. Besides, it is not easy to make such observations, because animal fathers and mothers, the latter especially, employ every possible means to screen their young from observation.

No greater error could be made than to assume that herbivorous animals, because of their gentler disposition, must be better parents than the carnivora. The lion and the tiger are unquestionably better fathers than the stallion and the bull. The same rule holds among birds. The hawk is surely a born murderer, yet the parental love exhibited by this bird of prey is

lifelike a manner. It must be explicitly stated, however, that only the female fox, or vixen, can claim credit for such devotion. The male fox, like all male canines, is an indifferent father and takes no care of his young, except when they have lost their mother.

Young foxes, according to Pagenstecher's observa-

mouth, and even when hotly pursued she will stop to pick up a young one and bear it to safety. It is very difficult to catch sight of the family at play. When the young foxes have grown larger they love to lie before the entrance to the burrow on pleasant mornings and evenings and await the homecoming of their



A FAMILY OF FOXES (CANIS VULPES).

tion, come into the world blind, and appear very stupid and helpless. They develop very slowly at first and do not open their eyes until the fourteenth day, or later. Meanwhile they have cut all their teeth. The mother treats them with great tenderness, remaining with them constantly during the first few days, afterward leaving them only for a short time at dark, and concealing their hiding place with jealous care. A month or six weeks after birth the little ruddy-gray coated fellows occasionally venture forth from the hole, to bask in the sun and frolic with each other.

parents. When this is too long delayed they howl and thus sometimes betray their hiding place. In July they begin to hunt, with their mother or alone, for young hares, mice, birds, and "such small deer," not despising even beetles.

In parental qualities, as in bodily structure, the monkey tribe stands nearest to the human race—a fact which is explained by the fundamental principles mentioned above; for monkeys, like men, are very helpless at birth and of slow growth. The orang-outang is supposed to require from sixteen to twenty years for complete development. The male monkey is so excellent a father that his many repulsive traits may be forgiven him, and his consort is a most affectionate mother. The spectacle of a monkey mother with her babe gives point to the German expression for doting material fondness, "Affenliebe" (monkey love). The excessive care lavished by female monkeys on their young was noticed even in antiquity, and Pliny asserts in all seriousness that monkey mothers hug their babes to death for pure love. No such cases have been observed in modern times, but many monkey mothers have died of grief after the death of their little ones.

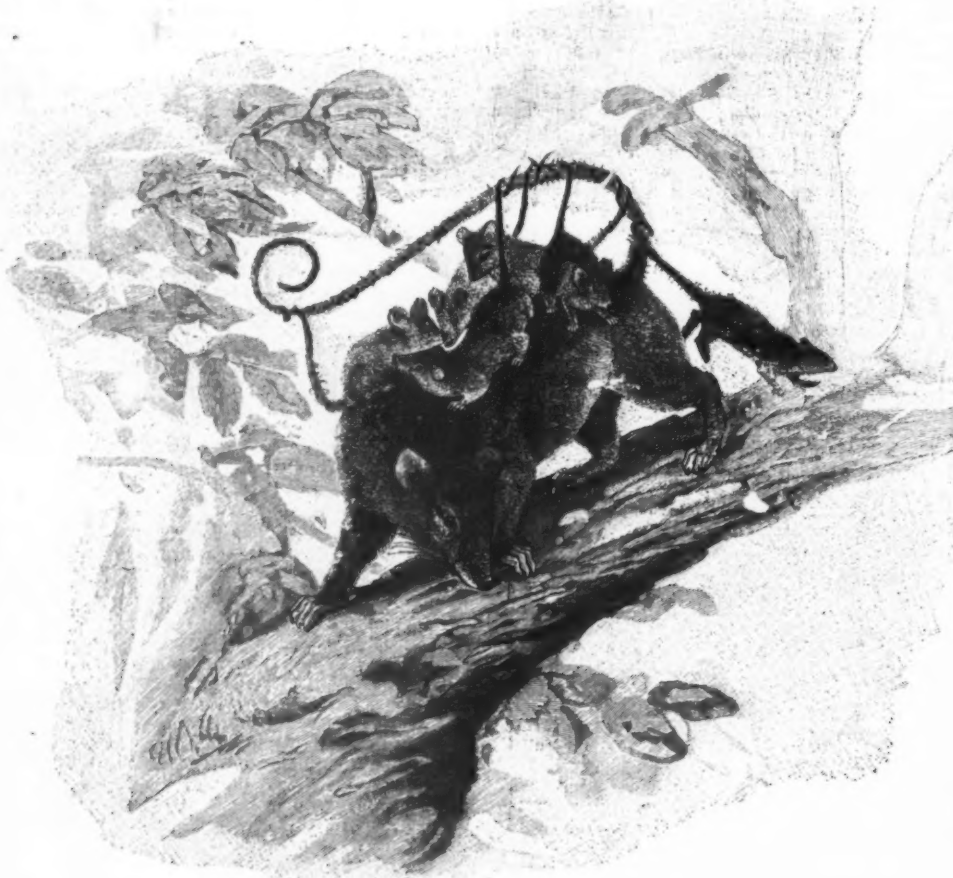
Very few persons have enjoyed the privilege of observing a monkey family in the wild state. Von Koppfels, however, had the good fortune to surprise the largest and rarest of monkeys, the gorilla, in the bosom of his family. For the sake of protection against his direst foe, the bloodthirsty leopard, the young gorilla remains with his parents until he reaches maturity at the age of fourteen years.

Von Koppfels describes the adventure as follows: "Peeping from behind an iba tree, I saw a gorilla family calmly eating fruit. It consisted of father, mother, and two young ones, apparently six years and one year old, judging from a human standpoint. It was affecting to see the loving care bestowed on the little one by the mother. The father, on the contrary, was concerned wholly with the satisfaction of his own hunger. When most of the fruit on the ground had been eaten the female climbed the tree with astonishing agility and shook down more fruit.

"Then the male gorilla, chewing as he went, betook himself to a nearby brook for a drink. I had not taken my eyes from him for an instant. Du Chaillu's stories and the fabulous exaggerations of the natives had caused the sight of the animals to throw me into intense excitement, but this vanished when the gorilla, having reached the brook, suddenly became alarmed and came, crouching, toward the tree which concealed me. But he had scented the foe too late, for I followed every movement with my rifle. Presently he stopped and stood motionless, staring at me. I fired, instantly reloaded and awaited his attack. Behind me stood my black attendant, trembling, with another rifle. But there was no attack, for the gorilla lay dead on the ground. The young ones screamed and fled into the bush and the mother sprang from the tree and hastened after them. In my excitement I forgot to fire at her."

Though gorillas live in single families, the long-tailed monkeys and most others are gregarious. The gorilla and the orang-outang, furthermore, seem to be of melancholy temperament, while the tailed monkeys are born humorists. Brehm describes an amusing scene of their wild life as follows:

"An attractive sight is presented by a troop of mon-



AENEAS RAT (DIDELPHYS DORSIGERA).

used by the hunter to capture it. The young birds are taken from the nest and the parents follow in order to feed them, and so these usually wary birds fall victims to their duty toward their young.

Therefore there is nothing exceptional in the self-sacrificing devotion to offspring shown by that arch-rascal Reynard, which the artist has illustrated in so

The mother brings them food in abundance, including, from the beginning, live mice, birds, frogs, and beetles, which she teaches them to catch, tease, and devour. She is now more wary than ever, suspects danger to her young in the most innocent objects and leads them back to the hole at the slightest noise. When hunted she carries them from one hole to another in her

keys engaged in foraging. Their boldness has amused me as greatly as it incensed the natives. When the troop feels itself secure the mothers allow their young ones to leave them and play with each other. Still the strict supervision of the young is not relaxed and each mother keeps a watchful eye on her own darling. But neither the mother nor the rest concern themselves with the general safety, which is left to the care of the leader of the troop. This guardian interrupts his feeding, from time to time, stands erect upon his hind feet and looks around him. If he has seen nothing disquieting he utters reassuring guttural sounds, but if there is any cause for alarm he gives vent to an indescribable, tremulous, goat-like cry of warning. His followers instantly assemble, the mothers recall their little ones and in a twinkling all are prepared to flee, taking with them as much food as they can carry.

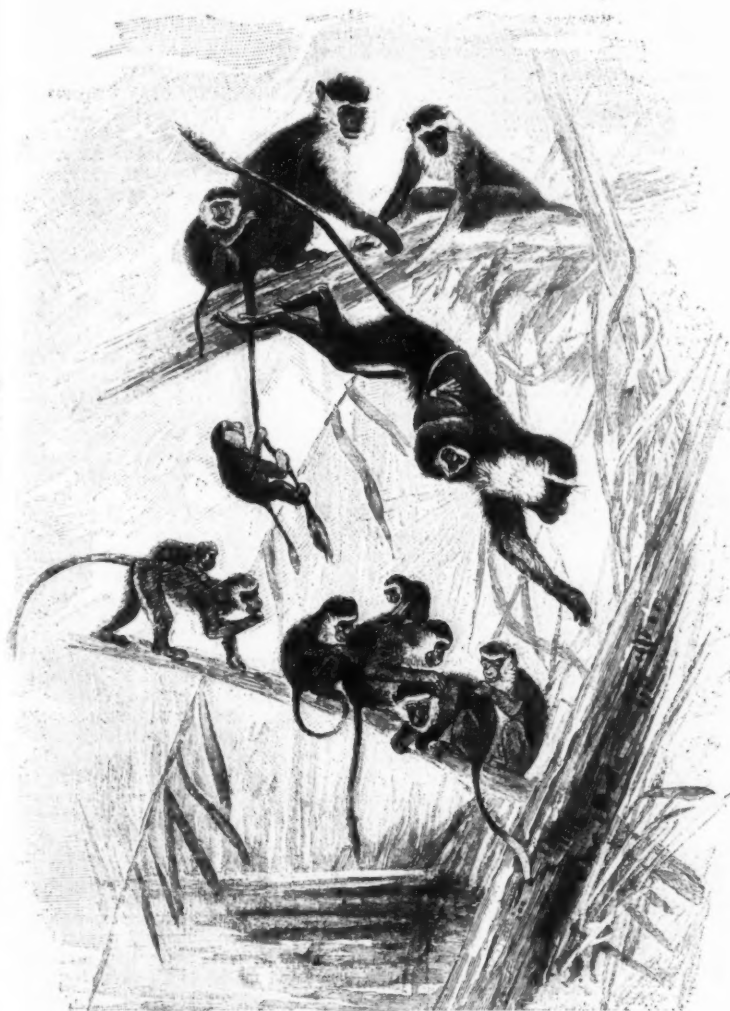
"When the leader thinks he has reached a place of safety he stops in his rapid flight, quickly climbs a tree, assures himself that all is well and conveys the assurance to his flock. When all have reassembled a task of some importance is begun. During the wild flight the animals have become covered with burs and thorns, and some of the latter have penetrated deeply into the flesh. Now they set to work relieving each other of these unpleasant appendages. One lies outstretched on a branch and another sits beside him and examines his pelt in a most thorough and conscientious

man soon leave the rudimentary pouch and are carried on their mother's back as the aged Anchises is said to have been borne from the flames of Troy on the back of his son Aeneas. Young birds and eggs are the food of this species of opossum, which is an expert climber and lives mostly in tree-tops.

It has already been mentioned that birds, almost without exception, are very good parents. But who would believe that there could be birds of which the male immures his mate in a cell during the brooding period, leaving only a narrow opening through which she can protrude her bill? Did not credible travelers agree in their descriptions of such prisons, the story might be credited to the late Baron Munchausen. This remarkable mode of incarceration is practised by the hornbills, birds with immense bills and horny crests, which inhabit southern Asia, the Malayan Islands, and central and southern Africa. In most, if not all, species the brooding female is walled up in a hollow tree and fed by her mate in the manner shown in the illustration. She remains confined in her prison until the eggs are hatched, and in some species until the young birds are able to fly. Meanwhile the mother has become temporarily incapable of flight, as she has moulted, or at least shed all her wing feathers, during her captivity. But the male is indefatigable in providing for his family, and is said to work so hard that he is reduced almost to a skeleton at the end of the brooding season.

no connection with other plants of the same name," belonging to the water-lily genus, symbols of Isis in Egypt and of Divine Beauty in India. It possesses a mountain-ash-like foliage, a brownish blossom and small berries like prunes, which were accounted good to eat. Of the wood, according to Pausanias, the statues of the gods at Megara were made.

In his *Metamorphoses* (ix. 346) Ovid relates how a beautiful nymph, escaping from the attentions of Priapus, became changed into a tree which bore her name, Lotus. It would be interesting could we ascertain which was the first example of this plant raised as a sacred one in ancient Rome, but that in all likelihood we shall not learn. One fact is noticeable regarding the specimens recorded by historians as having flourished—namely, that they nearly all occur within an area of a few hundred square yards. This suggests that birds may have carried the seeds from temple to temple, though very few took root. A lotus tree, we are told (Pliny says "planted by Romulus," "ex victoria de Decumis, aequiva Urbi intelligitur"), grew on the Volcanal beside the temple of "Concordia," and in this protected position it so survived as ultimately to thrust its roots into the Forum Julium ("per stationes Municipiorum," Plin. H. N. xvi. 86), a topographical record of no little importance. From the same source we learn that yet another flourished on the opposite side of the same temple of Concordia—namely, toward the temple of Saturn. Pliny, however, informs us regard-



GREEN MONKEYS (CERCOPITHECUS SABAEUS).



A RHINOCEROS HORNBILL (BUCEROS BICORNIS) FEEDING HIS CAPTIVE MATE.

tion manner, removing every bur and extracting every thorn. Chance parasites are not neglected but are diligently hunted down and eagerly devoured. The illustration shows a group of green monkeys (*Cercopithecus sabaeus*) engaged in this interesting occupation."

The young of the marsupials are born in an even more helpless condition, in some respects, than those of men and monkeys. Most of the animals of this remarkable order, including the best known, the kangaroo, are denizens of Australia; the rest are found in America. The essential points in which marsupials differ from mammals are these:

The young marsupial, after a very short term of uterine gestation, is born in a very undeveloped condition and at once placed by the mother in her abdominal pouch and attached to a teat, to which it adheres, suckling, until its limbs and organs of sense have developed. During this period the pouch is not only a nest and place of refuge but, as it were, a second womb. Afterward the young marsupial makes excursions, of ever increasing length, from the pouch, but its entire period of development is passed therein, and in several species, in which true uterine gestation continues little longer than a month, the young are carried in the pouch six or eight months.

The illustration shows the Aeneas rat (*Didelphys dorsigera*) somewhat smaller than the common rat, and a native of Surinam. The young of this marsu-

According to the theory of many natives the female is imprisoned to prevent her neglecting her duty of brooding, and if she has been unfaithful or negligent her mate closes the little window of her cell and abandons her to a painful death by suffocation. The true story, perhaps, is this: The female walls herself in, so that she cannot fall from the nest after losing her feathers, and also to protect herself from enemies. The building material is her own excrement. This version is less poetical than the other but it is probably nearer the truth. It is supported by the statement that the female liberates herself as soon as the young birds are well grown, so that her prison is less formidable than it appears.

At all events it is certain that raising a family involves extraordinary exertions on the part of the parents, or, at least, of the father.

THE SACRED LOTUS TREE.

Among the most conspicuous trees which were both sacred and ornamental in ancient Rome was the lotus tree, otherwise *Diospyros Lotos*. The plant may have been imported from Africa in the early days of Roman maritime power. The name having been applied to quite a number of different plants, has led to no little confusion, and this confusion is of old standing, for Pliny himself fails to make necessary distinctions between one and another. Suffice to state that it "had

ing a still more remarkable specimen than these. This grew in the atrium of the temple of Juno Lucina, on the Cisplan portion of the Esquiline. In it several men could stand together upright. Gossip gave this tree a greater antiquity than the temple itself, which had been built in 374 B. C. There likewise seem to have been beautiful examples of the same tree planted on the Palatine, probably hard by where the casino of the Farnese now stands—namely, in the gardens of Lucius Crassus, the orator, the same whom Cicero nicknamed the "Palatine Venus." Cicero, however, purchased the house himself in the year 62 B. C. in order to enjoy increased splendor. One of its peculiar attractions, we read, consisted in a peristylum containing six great lotus trees. These outlived their various masters, until we hear of Cæcina Largus, Consul in A. D. 42, being the proud possessor, and showing them to his friends. They may have perished in Nero's fire.

But the most interesting example of all was a lotus tree whose appearance must have seemed truly portentous, and that not merely from its great age, which is given as 500 years, but because it was hung with virginal tresses of hair, and was therefore termed "Capillata." This grew in the garden-court of the Vestal Virgins, and the tresses dark and fair upon its boughs had belonged to those ladies themselves. I believe that the novice of to-day, on entering an order of nuns, loses her hair ruthlessly, once and forever. On the other hand, the vestal, upon initiation, lost her

tresses, but only once, and for a time. The surviving statues clearly reveal that they were permitted to grow again. Whether they were removed again and again in accordance with any as yet unknown votive ordinance it is not possible to determine. The severed tresses, at any rate, were taken and attached (possibly ticketed with the owner's name and date) as votive tokens to the lotus tree (Plin. H. N. xvi. 85). What was ultimately done with them who shall say? We do not yet know where the Vestals were buried! Their convent has been thoroughly explored for the first time by Commandatore G. Boni, but the exploration has not revealed this secret.

The question arises, Why was this custom observed? It would be manifestly difficult to explain this, except as a survival of tree worship—that is to say, the trees had originally served as a very personal substitute for its owner, dedicated to a tree-deity, and in later days may have been regarded as a symbol of purification, typifying severance from the secular world. The cropped hair of the Flamen Dialis had to be buried under an arbor felix. It would be interesting to know how this particular tree got there. It is possible (but not probable) that the earliest "Nemus Vestæ" was composed of lotus trees, of which this was a survivor and representative. There may be reason to connect it with the medical divinites (Pausanias, 2, 22, 5; and 1, 35, 3). For Diospyros Lotus is the green ebony tree.

The "Nemus Vestæ" was probably much reduced in extent before Caligula pushed northward the line of the Nova Via for the purpose of overbrowsing the Forum with his gigantic palace (Domus Calii). If any shred of it survived, it must have perished in the fire of Nero, A. D. 65. New Zealanders still offer locks of hair to sacred trees at fords of rivers and landing places. The Malabarese exorcise demons from possessed folk by cutting off their hair and hanging it on a tree as a propitiation to the wood fiend. Tylor says there is ground for interpreting the consecration of a boy's hair in Slavonic countries as a representative sacrifice. After all, do we not still have our Christmas trees, and decorate them with yellow tinsel still called "angel's hair"?

In passing to another sacred plant, I will merely notice what is apparently a coincidence connected with the lotus tree. Dioscorides states plainly that a decoction of its juice—but it scarcely seems to have been the Diospyros of which he was speaking—is exceedingly beneficial both for dyeing the hair yellow and for preventing it falling out. *Rubricat capillos, et stringit eorum radices ne cadant*, and Galen confirms this finding. Whether or not it may have been *de rigueur*, for any state reason, for the Vestals to adopt a particular color or tint for their hair, evidence is not at hand to prove. But yellow or golden hair was fashionable, and probably a Hellenism, which survived throughout the empire until the Middle Ages, with the Angevins ("flavi leones") and Venetians. Probably fair hair was a token which helped the Flavian dynasty to popular favor, seeing that, according to one tradition, Romulus and Remus were fair-haired ("flavæ comæ"), as also was "the goddess Roma." It is interesting to find this lotus still known in southern Italy as "legno santo."—St. Clair Baddeley, in the Nineteenth Century.

THEORIES OF ORE DEPOSITION HISTORICALLY CONSIDERED.*

By S. F. EMMONS.

In the city in which we meet this year an exposition is preparing which is designed to commemorate the peaceful acquirement a century ago of the rights of France to the Mississippi Valley and the regions to the west. It was the metallic wealth of the valley region which first led to its exploration by the French, and which still constitutes an important feature in its industry, yielding annually, as it does, an amount about equal to the original purchase price. To a still greater degree has the unexampled rapidity with which, in the last half century, civilization and industry have spread over the mountainous regions of the West been due to the development of their mineral resources—a development to which geological science has in no small measure contributed.

In selecting a subject for my address as president of the Geological Society of America it has seemed appropriate, therefore, both to the time and to the place, to choose a theme that has to do with that branch of geology which is especially concerned with the deposits of the metals. The history of theories of ore deposition was the subject originally chosen, but, as it gradually developed in the course of research, it was found that anything worthy of that name would far exceed the proper limits of an address. Thus its scope has been gradually narrowed to fit the necessities of the occasion, until it has become little more than a brief enumeration of the opinions held from time to time within the historic period which seems to have left the most permanent impress upon the minds of geologists.

The term "ore deposition," which is used in preference to its earlier synonym "vein formation" as more correctly representing the broader conceptions of the present day, applies, it is hardly necessary to state, only to the processes involved in the formation of deposits that form an integral part of the rock in which they occur, or "rock in place," as is the legal phraseology of the day, and does not include such recent detrital deposits as placers, etc., about whose origin there has never been any wide divergence of opinion.

* Annual address by the president of the Geological Society of America, read before the society at St. Louis, Mo.

PREHISTORICAL VIEWS.

The historic period is assumed to have been entered on only with the revival of learning about the time of the Reformation at the commencement of the sixteenth century. What few records can be found of genetic opinions held before that time, even as to the more striking and readily observable geological phenomena, such as volcanic eruptions, earthquakes, and changes in the earth's surface, are too scattered and fragmentary to afford evidence of any continuous development of thought. The views of the Pythagorean and Aristotelian schools of philosophy on the causes of these natural phenomena, though apparently based more on bold poetical fantasy than exact observation, present a clearer and more logical conception than that which obtained nearly twenty centuries later. Thus it is said that as early as 600 B. C. the observed occurrence in the rocks of casts of shells and plants were ascribed to periodical floodings of the land. During the Middle Ages, however, under the monkish influence that discouraged any views that might throw doubt on the literal correctness of the Mosaic cosmogony, these fossils were variously assumed to have been formed in place by the agencies of the stars, to have been transformed from rock by some plastic force (*vis plastica*), or left by the waters of the Noachian deluge.

Among the early cosmogonies, which it is true are of mythologic rather than of scientific interest, the Chinese is the only one which included metal among the elements of creation. Yet the general use of the metals, whose extraction from their native ores presupposes a knowledge of the art of smelting—in itself an evidence of a certain insight into nature's processes—goes back to very remote antiquity. It seems possible that the philosophers of these earlier civilizations may have indulged in speculations as to the origin of the metals, but if so they left no written record. Even among the Romans, of whose proficiency in mining evidence is found in most of the mining regions that came under their control, little or no genetic speculation was indulged in. If we accept the evidence of Pliny's "Natural History." This monumental work, which is assumed to contain a complete and faithful presentation of the knowledge of natural phenomena at the opening of the Christian era, though it described in considerable detail the methods of mining then in vogue, does not even attempt a description of the mode of occurrence of the ores, much less speculate on their origin.

The historic time here contemplated may be divided, in a general way, into three periods, according to the prevailing method by which the views then current were arrived at.

DEVELOPMENT OF KNOWLEDGE HISTORICALLY CONSIDERED. The Three Periods.

1. The speculative period, in which, from a few rather imperfectly determined facts of nature, general theories were evolved intended to be applicable to all natural phenomena. It was a period in which geology was not yet recognized as a distinct science and had hardly reached the dignity of an adjunct to mineralogy.

2. The second period was that in which facts of observation had accumulated sufficiently to establish geology on the basis of a distinct science, but in which the method of reasoning from generals to particulars still prevailed. This was the first scientific period.

3. The third period might be called the period of verification, in which the theories already propounded were tested by experiment or observation.

Such a classification is in the nature of things not susceptible of a very definite demarkation either in point of time or in the assignment to either period of individual opinions or theories, but the attempt to make it, however imperfect and unsuccessful it may prove, will assist us to form a clearer conception of the progress of human thought and of the methods by which it has arrived at its present understanding of the particular branch of geological science which we are considering.

The Speculative Period.

During the first or speculative period, which may be assumed to have extended up to the close of the eighteenth century, or to the time of Werner and Hutton, the accumulation of accurately determined facts that would bear on the theory of ore deposits was so extremely limited that it may be assumed to have exercised but little influence on the development of the science beyond the suggestion it afforded to later students of lines of investigation to be followed, and hence may be passed over in a very cursory manner.

In the speculations of this period which especially influenced the development of opinion two general types may be distinguished:

First. The broader theories of the cosmic philosophers with regard to the formation of the earth, based more or less upon astronomic data.

Second. The special theories of mineral vein formation conceived by individuals and based in the main on general conceptions which were supplemented by a certain amount of personal observation and experience.

The cosmic philosophers were men who, without being geologists in the modern sense of the word, nevertheless put forth ideas with regard to the system of the earth that had an undoubted influence on the minds of those who have since made a special study of this part of science.

First of these was Descartes, the French mathematician and founder of the Cartesian system of philosophy (Principia, 1644), who considered the earth a planet like the sun, but which, though cooled and con-

solidated at its surface, still preserved in its interior a central fire that caused the return toward the surface of waters of infiltration, the filling of veins by the metals, and the dislocations of the solid crust.

Nearly contemporary with him was Steno, a Danish physician, who spent the greater part of his life in Italy, where he devoted much of his time to the study of geological phenomena. He was the first to seek to learn the origin of rocks and the changes in the earth's crust by the inductive method. He wrote a remarkable treatise, bearing the quaint title "De Solido intra Solidum naturaliter Contento" (1669), in which he considers vein fissures to be later than the inclosing rocks and their filling to result from the condensation of vapors proceeding from the interior. Steno's ideas, so much in advance of those of his age, seem to have found little favor among his contemporaries, and were scarcely known among geologists until called to their attention in the first half of the nineteenth century by de Beaumont and von Humboldt.

Later Leibnitz, a German philosopher, inspired both by the ideas of Descartes and the observations and deductions of Steno, wrote a work on the origin of the earth (Protogæa, 1691), which, in spite of its necessarily limited basis of facts, bears the imprint of genius in its conceptions. In applying his theories to the veins of the Hartz, which he had occasion to visit during his thirty years' sojourn at Hanover, Leibnitz considers that they have been filled sometimes by the liquefying action of fire, sometimes by water.

In the following century Buffon, the great French philosopher, excited to the highest degree the attention of the scientific world by his *Théorie de la Terre*, 1749, and *Époques de la Nature*, 1778. His conceptions, though striking by the brilliancy of their imagination, have for the most part not proved of enduring value. Nevertheless they served a purpose by stimulating more exact observations on the points with regard to which his views were contested. With regard to mineral veins he held that they were primarily fissures opened in the mountains through the force of contraction, and that they were filled by metals which by long and constant heat had separated from other vitrifiable materials. But as there are non-vitrifiable as well as vitrifiable materials in veins, so there are secondary veins which have been filled with non-vitrifiable minerals by the action of water. The primary veins he considers to be characteristic of high mountains, while the secondary veins occur rather at the foot of the mountains, and probably derived some of their material from the primary veins.

In the second class the foremost place, both in time and in the importance of his actual observations, must be accorded to Dr. George Bauer, better known by his Latinized name of Agricola, a German physician who flourished during the first half of the sixteenth century. He spent a great part of his life among the mines of Saxony (Joachimsthal), of which he made a careful study. He wrote in most excellent Latin several works on mineralogy and on the art of mining, which were for centuries standard books of reference on these subjects, and even to the present day contain much of interest to the mining engineer. Agricola was first and foremost a mineralogist, and all his work was characterized by acuteness of observation and accuracy of description, though in strong contrast to most of the early writers he did not indulge much in earth-formation theories. He divided mineral veins into "commissure" (joints or rents), "fibre" (small branching veins), "vena" (large veins or channels), and "terre canales" (vein systems), and gives a clear account of their size, position, intersections, etc. In theoretical matters he was less definite and satisfactory.

During all this period the two main subjects of speculation with regard to mineral veins, which term practically included all ore deposits, were (1) their age relative to the rocks in which they were found, and (2) the cause and manner of their filling; and in considering the views put forward on these subjects we must bear in mind that chemistry as a science only came into existence toward the end of the eighteenth century, hence the ideas which were entertained as to the processes that may have gone on within the earth's crust to form metallic deposits were necessarily somewhat vague and fanciful.

Among the ideas current in his time Agricola, as a result of his observations, promptly rejected the views that veins were formed contemporaneously with the primary rocks of the globe and that the planets had an influence in the formation of the metals, but he seems to have had very few positive ideas of his own as to their origin, though inclining to ascribe vein filling to material brought in by circulating waters. He still entertained the idea of a lapidifying juice, which he conceived as giving to water the power of absorbing earth and of corroding metals, and which might have formed fossil casts as well as minerals. His use of the term "fossilla" for both minerals and petrifications, which was retained by subsequent geological writers, especially those of the Wernerian school, is often a cause of misconception among modern readers who have occasion to consult the older works on geology and mineralogy.

For over a century after Agricola there appears to have been little written that had any special bearing on ore deposits, but toward the close of the seventeenth century there was an apparent awakening of interest in regard to their origin among reflective men who had to do directly or indirectly with mines, which may probably have been prompted by the theories of the cosmic philosophers, so that by the close of the eigh-

teenth century there had accumulated considerable speculative literature on this subject.

The following is a list of the more frequently quoted works that appeared during this period, with the approximate dates of their publication:

Speculum Metallurgie politissimum, by Bergmeister Balthasar Rösler (1700).

Physica subterranea, by J. J. Becher. Commentated by G. S. Stahl. Second edition (1703).

Pyritologia, by J. F. Henkel, professor of chemistry and mineralogy, Freiberg (1725).

Obersächsische Bergakademie, by C. F. Zimmermann, councillor of mines (1749).

Markscheidekunst, by Von Oppel, vice-director of Saxon mines (1749).

Abb. v. d. Metalmuttern, etc., by D. J. H. Lehman, director of Prussian mines (1753).

Elementa Metallurgie Chemicæ, by W. J. Wallerius, Stockholm (1768).

Ursprung d. Gebirge u. Erzadern, etc., by C. F. Delius, professor of metallurgy at Schemnitz (1770).

Mineral. Geograph. d. Kursächsischen Länder, by J. F. W. de Charpentier, director of Saxon mines (1778).

Usterirdische Geographie, by I. G. Baumer, Glessen (1779).

Gesch. d. Metallreichs, by C. A. Gerhard, councillor of mines (1781).

Erfahr. ü. d. Innern d. Gebirge, by F. M. H. v. Trebra, vice-director of Hanoverian mines (1785).

Beobacht. ü. d. Hartz Gebirge, by Lieut. G. O. S. Lasius, engineer on land survey of Hanover (1787).

The views of most of these early writers were rather curious than instructive, yet some of them, especially those of men who had the largest practical experience in mines, are remarkably suggestive.

Rösler, the earliest recorded mine superintendent, recognized that veins differ from ordinary cracks in the rocks only by being filled with metallic minerals, but did not speculate on their genesis. Becher and his commentator, Stahl, both professors of medicine, assumed in a general way that mineral veins were original cracks in the rocks containing matter that had been changed into vein minerals by some exhalations from the interior. Henkel supposed further that certain kinds of rock or stone which served as matrices were favorable and even absolutely necessary to the formation of vein minerals. Zimmermann, who, like Henkel, was a chemist rather than a miner, considered that the material of veins, originally the same as the inclosing rock, had been altered by some saline solution and thus prepared for its final transformation into metallic minerals. The above, which might be called conversion theories, do not necessarily assume that veins are mechanically formed cracks, and hence of more recent formation than the inclosing rocks.

Von Trebra, a director of mines who was seeking for facts to aid in their exploitation, thought the changes observed in mountains took place slowly under the influence of heat and humidity, and expressed his idea of conversion as applied to veins more distinctly as the taking away of one constituent of a rock and replacing it by another. The agent of the transformation he called putrefaction or fermentation, by which names he wished to designate some unknown force which produced the chemical changes observed in the rocks.

Lehmann, a mineralogist and also a director of mines, supposed that the veins found in mines are only the branches and twigs of an immense trunk that extends to a great depth in the bowels of the earth, where nature is carrying on the manufacture of the metals, and whence they travel toward the surface through rents in the rocks in the form of vapors and exhalations, as the sap rises and circulates through plants and trees. This general view is popular among practical miners even at the present day, probably because it appeals almost exclusively to the imagination.

Delius, Gerhard, and Lasius had the general idea that veins were fissures formed later than the inclosing rocks, which had been filled by materials brought in by circulating waters. The last went so far as to suppose that these waters contained carbonic acid and other solvents which enabled them to gather up metallic materials in their passage through the rocks. In this respect he approached closely to modern views, but he was in doubt whether the metals were contained in the rocks as such, or whether the solvents possessed the power of turning the substances they encountered in one place into lead and in another into silver or some other metal.

Of more permanent value were the works of Von Oppel (1749) and de Charpentier (1778), who were successively directors of the Saxon mines previous to Werner.

Von Oppel was the first to distinguish bedded deposits (*lagergänge*), or those which lie parallel with the stratification, from true veins. He also gave to the small branches from a main vein the name of "stringers" (*trümmer*), and noted that veins sometimes shift or fault the strata they cross, in which case he calls them "shifters" (*wechsel*). He laid stress on the importance of the causes which have produced rents or fissures in the earth, and shows how in the formation of mountains the rocks, being exposed to great desiccation and violent shocks, might split from one another, thus producing rents with some open spaces, which being afterward filled, would form mineral veins.

"Where a vein has been cut or deranged by a visible rent," he remarks, "it is again to be met with by following the direction of this last."

Charpentier was a careful observer and a very cau-

tious theorizer. He says, "Natural history will always gain more from true and accurate descriptions of her phenomena than from many and yet too-early explanations offered for them"—a most excellent principle which he admirably carries out in his own work. He presents many arguments derived from his own extensive observations in mines against the prevalent theory that veins were once open cracks formed by contraction, and that they had been filled by material flowing in from the surrounding rocks and hardening in them. Some of his objections were:

That contraction could not have made the kind of fissures that the veins are found to fill.

Open or empty spaces could not have existed under the conditions present when they were formed; pressure would have closed them.

The fragments of country rock as found in veins could not thus be accounted for. If they had simply fallen into an open crack, they would have accumulated at its bottom.

The comparatively uniform arrangement of ore in the vein, the enrichment caused by the crossing of one vein by another, the transition from vein material to country rock, etc., could not be explained on the contraction theory.

Having given his reasons why he believes that veins are not the filling of wide open spaces in the rocks, he says his readers will naturally ask how he supposes them to have been formed, and although he is not anxious to present a theory, he says he cannot see from his observation of the workings of nature any other method for the formation of veins or other ore deposits than by an actual transformation of the rock material. Nature's processes have created innumerable small cracks and fissures in the rocks, and when a great number of such cracks lie together and in a common direction they might give rise to a considerable vein deposit. Vapors bringing in mineral solutions might penetrate these small cracks, as the sap rises in capillary tubes in organic bodies. If thereby the intermediate rock mass became changed into vein material, a vein deposit might be created without the necessity of wide empty spaces for its reception.

Rather more than usual space has been given here to Charpentier's work because of the striking contrast of his mental attitude with that of his great successor, Werner, whose reputation so completely overshadowed him that he has received less notice from later writers than seems to be his due.

(To be continued.)

PORCELAIN.

By DR. EDUARD BERDEL.

ALTHOUGH porcelain has been made in Europe for a hundred and fifty years, most persons know so little of its nature and manufacture that an easily intelligible explanation should be of general interest.

Porcelain is distinguished from ordinary pottery by the purity of its color, its density, its smooth, vitreous fracture, and its translucency. The superficial glaze is not a necessary characteristic, as it is a separate layer, applied to the finished porcelain.

The principal ingredient of porcelain, of course, is the substance which enables it to be molded into any desired form before it is burned or fired. Herein we see the distant relationship which porcelain bears to common potter's ware. Marl, loam, porcelain clay, and other clays all contain, mixed with larger or smaller proportions of other ingredients, a substance which may be designated as "pure clay." This is a compound of alumina, silica, and water, and has the chemical formula $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$. The paste, or dough, produced by mixing this pure clay with water may be kneaded into any shape, which it retains perfectly on drying, and the mass may then be solidified and hardened by burning. As in this process all its water, including that which had been chemically combined, is lost, it is evident that the volume must be diminished—the mass "shrinks." If the firing were pushed to the highest temperature that can be produced artificially, the clay would finally fuse to glass, but up to temperatures very near this extreme point, it retains its external form perfectly, no matter how much it may shrink. Herein is shown the second invaluable property of this material. Not only is it "plastic," or capable of being molded into any form, but it retains this form after firing. It is fire-resistant, or it "stands fire."

This pure clay constitutes less than half the weight of common loams and potter's clays, in which it is mixed with various sorts of mineral residues, which are much more fusible than pure clay and bring it, also, to fusion at comparatively low temperatures. The presence of these easily fusible minerals—"fluxes," the chemist calls them—makes it necessary to fire common pottery at a low temperature. The impure clays also contain numerous coloring matters—iron, manganese, titanic acid, vanadic acid, etc.—which gives the finished ware a red or dirty brown color. These two facts make such clays quite unsuitable for the manufacture of porcelain. That the muddy color does so is readily intelligible; the effect of the melting of the flux and its action on the clay will become clear presently.

Porcelain clay, or kaolin, may be regarded as practically pure clay, with no admixture worth mentioning. Objects formed of kaolin and fired at a high temperature are hard, white, and of perfect shape, but still they are not porcelain. Fragments of such vessels lack two of the characteristic properties of porcelain—its dense, glass-like texture and its translucency. Kaolin, fired alone, always remains porous and opaque. If the firing temperature is gradually increased, these

properties persist to the end when, almost without warning, the whole vessel collapses and fuses to a shapeless mass. Density and translucency, therefore, must be sought by other means than extremely high firing.

If a thin-walled porous vessel is thoroughly saturated with water, it becomes translucent, unless it contains much opaque coloring matter. This phenomenon, which is very surprising the first time it is witnessed, explains the whole secret of porcelain manufacture. To make porcelain it is merely necessary to contrive that the pores of the burned kaolin shall be filled with a transparent substance resembling glass. In this way the ware will become dense and translucent without losing any of its sharpness of form.

The accomplishment of this object, however, is not a simple task. The obvious method would be to mix the clay with a substance that would melt in the firing, a flux that would assume on cooling a vitreous, not a crystalline form. But the realization of this idea is more difficult than one would think. Most fluxes act very energetically on the clay, and cause it to melt with them. In other words, when the flux melts, the clay framework loses its rigidity, and the flux, instead of quietly filling its pores, destroys the whole structure.

Here we are reminded of the common clays which, as we have seen, are mixtures of pure clay with various natural fluxes. It might be supposed that such clays form natural porcelain mixtures, as they contain both the pure clay and the flux to fill its pores and make it translucent. But this theory fails in practice, for the reason just given, that when the flux melts it carries everything with it.

So we must mix with the clay a substance which melts without seriously affecting the clay framework, of which it fills the interstices. To use a technical expression referring to the fusion of the flux alone, the "sinter" point must be much lower than the melting point of the whole mass. It is this condition that makes the manufacture of porcelain so troublesome, and that has raised it to the dignity of a difficult art. The fulfillment of this condition long remained a secret, an "arcanum." It may be noted in passing that, until within a few decades, the chemists of the royal porcelain manufactory in Berlin were known as "arcanists," and their assistants as "arcanist pupils."

To return to our fluxes, the Chinese are better off than we are, for their kaolins generally contain by nature fluxes of such character and in such proportions that in firing they satisfy of themselves the condition which we have taken as our necessary point of departure. Chinese kaolins, as a rule, are ready-made porcelain mixtures. This is not the case with European kaolins. We have clays that contain fluxes, and are not quite so unsuitable as those described above. Such clays are actually employed in the manufacture of vessels of many sorts, but most of this ware has a muddy color and, therefore, is not translucent, despite the "sintering" of the flux. It is known as stoneware (*Steinzeug*).

On the other hand, our white-burning kaolins and clays are usually found unmixed with flux, which must be supplied artificially. Countless unsuccessful attempts have been made to discover suitable fluxes, and the results of the successful experiments have been jealously kept secret. Usually the choice has fallen upon felspar, a compound of potash, alumina, and silica ($K_2O \cdot Al_2O_3 \cdot 6SiO_2$) which melts at about 1,200 deg. C. But with felspar or similar materials two new difficulties are introduced. We have already seen that pure clay shrinks greatly in firing. The addition of the felspar flux, which always attacks the clay to some degree, greatly increases the shrinking, and therefore has an unfavorable effect on the product. Besides, though the felspar melts and fills the pores of the clay, it does not remain glassy on solidifying, but forms thousands of minute crystals which greatly impair the translucency of the ware.

These two difficulties are overcome by means of a copious addition of quartz (silica). The quartz expands considerably in the firing, and thus compensates for the shrinking of the other ingredients. Besides, though the quartz raises the melting point of the felspar, it prevents the latter from crystallizing, and thereby causes it to retain its glassy appearance.

To make porcelain, therefore, pure clay, quartz, and felspar are mixed in various proportions, according to the particular quality of ware desired, and the mixture is molded and fired.

If quartz alone is added to the clay the product is a hard, white, opaque, and porous ware, which shrinks but little in firing. This is known as earthenware (*Steingut*). Faience is a dark-colored earthenware, covered by a white, opaque glaze, to which decoration is applied. Majolica is a variety of faience with a distinctive polychrome ornamentation which, in some instances, is applied, not to an intermediate opaque white glaze, but directly to the body of the ware by means of opaque colored glazes. These wares have a certain kinship with the common pottery mentioned in the beginning of this article. Just as stoneware is an inferior porcelain, so is common pottery an inferior earthenware. The lines of demarcation between ceramic products, however, are by no means as sharply drawn in practice as they are drawn here, in order to elucidate the principles of the art.

To return to porcelain, a brief mention must be made of its glaze. This is a finely ground, easily fusible mixture of various fluxes suspended in water. The porcelain vessels, after being fired at a low temperature, which operation leaves them porous, are dipped in this mixture. The water is absorbed, and the glaze

remains as a fine powder on the surface of the ware. In the subsequent "high firing" the glaze melts, and in cooling forms a glassy coating. All porcelain, therefore, is fired twice, because the glaze can be best applied in this way. But, very remarkably, the name "biscuit," meaning "twice baked," is given only to unglazed porcelain, which is put through the same ovens merely for the sake of convenience. Glazed porcelain, also, is "twice baked," but potters do not potter with philology!—Translated from Prometheus.

THERMOMETERS, PYROMETERS, AND THERMO-REGULATORS OPERATED BY THE PRESSURE OF SATURATED VAPORS.

THERMOMETERS AND PYROMETERS.

THE rapid and exact determination of temperature is very important, both in pure science and in tech-

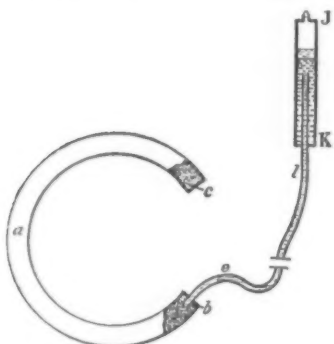


FIG. 1.—DIAGRAM ILLUSTRATING PRINCIPLE OF SATURATED VAPOR PYROMETER

nology. The well-known complications which accompany the employment of the ordinary liquid and air thermometers, expanding pyrometers and electrical thermometric devices may be avoided by the use of saturated vapors. As the tension of a saturated vapor is a function of the temperature alone, necessary or accidental variations in the volume of the containing vessel cannot affect the reading of the instrument. And every condition occurring in practice can be met by selecting, as the liquid vaporized, a liquefied gas, a substance ordinarily liquid or a fused metal, according to the temperature to be measured.

The essential part of the apparatus is a steel tube of elliptical cross-section, bent into the shape of a torus, or ring (c a b, Fig. 1). This tube is filled with an inert substance of small expansibility, such as sand, and the ends are plugged and sealed. The plug b is traversed by a flexible tube d e l of indefinite length, of small or capillary bore, which is soldered to the plug and communicates with the interior of the large tube. The other end of the capillary tube is connected with a reservoir of measured capacity, consisting either of a single tube, J K, or a battery of tubes, of metal. In either case the open end of the capillary tube is placed at the geometrical center of the reservoir, so that every plane passing through it divides the reservoir into two equal parts.

The curved tube b a c and the long capillary tube are filled, and the reservoir is more than half filled, with oil, mercury, or other non-volatile liquid above which, in the reservoir, are placed a few drops of a liquid which will assume the condition of saturated vapor of considerable pressure at all temperatures for which the apparatus is designed. The reservoir is then closed.

The little reservoir J K, consisting of one or several small tubes, is the only part of the apparatus that is directly affected by changes of temperature. Under the influence of such changes the tension of the saturated vapor varies and determines, in the large tube b a c, through the intermediation of the non-volatile liquid, corresponding movements of extension and contraction. If the end b is fixed and the end c is free, the movements of the latter will indicate all the

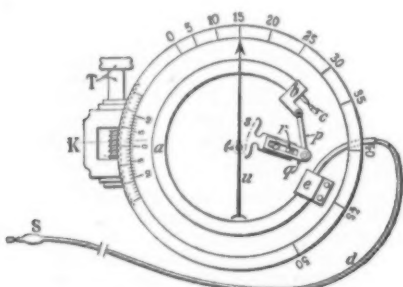


FIG. 2.—DIAL THERMOMETER.

changes in temperature experienced by the reservoir J K.

In the dial thermometer, or pyrometer (Fig. 2) one end of the motor tube is fastened to the rigid bottom of a metal case while the movements of the free end are transmitted by the link p to the lever q. The other arm of this lever, of adjustable length, bears the toothed sector s which engages with the pinion t, rigidly attached to the pointer u. The sector and the pivot on which the lever turns are fastened to the

rigid base to which the fixed end of the tube is attached.

The flexible tube, e d s, which may be ten, fifty, a hundred meters in length or even longer, passes through the side of the case. In the apparatus shown in Fig. 2 it terminates in the bulb s, of the size and shape of a small bird's egg, which is, practically, the only part of the apparatus that is sensitive to heat. If the whole of the long communicating tube is coiled up and immersed in a bath of any temperature between the extreme limits of the apparatus, while the bulb is kept at a constant temperature, the pointer moves slightly but returns exactly to its former position. There is no permanent deflection unless the bulb is immersed in the bath. From this fact it will be understood that, with this apparatus, one can sit at his fireside and observe the temperature at any desired point out of doors.

The graduation of the apparatus may appear very troublesome, because the degree marks are not equidistant, but it may be made very easily and with perfect accuracy with the aid of a thermo-regulator capable of maintaining a constant temperature in a large mass of liquid.

With a thermo-regulator based on the same principle as the thermometers under consideration and regulating the temperature to about one-twentieth of a degree I have had no difficulty in graduating such thermometers, by comparison with a standard thermometer, to fifths of a degree.

In the self-registering thermometer or pyrometer (Fig. 3) the motor tube may make several complete turns. The displacements of its free end, b, are transmitted to the recording lever and pen, u, by the intermediate levers, g g', and the links, p p'. The drum, O, and a second drum, O', behind it, are driven uni-

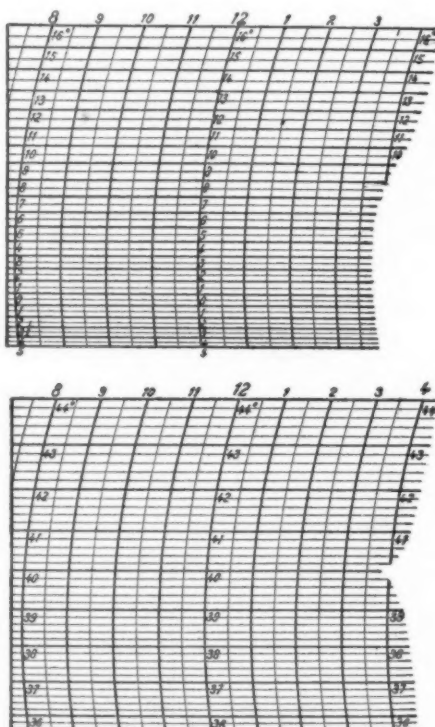


FIG. 4.—RULED PAPER FOR SELF-REGISTERING THERMOMETER.

formly by clockwork in the interior of the former. O' bears a roll of paper, suitably ruled. Fig. 4 illustrates sheets ruled for the intervals of temperature —5 deg. to +16 deg. and 36 deg. to 44 deg. The horizontal lines represent degrees and fractions of degrees while the curves indicate hours and half hours. The intersections of the pen-trace with these two systems of lines permit the temperature of any moment of the day or night to be reviewed at leisure, and as the flexible tube, e d s, may be extended indefinitely a continuous record may be made of the temperature at a point a kilometer or more distant from the drum.

The astonishing sensitiveness of the apparatus is indicated by the fact that the interval of temperature 36 deg. to 44 deg. measures 80 millimeters on the paper. (The figures are 5% of the actual size.) In this part of the scale, therefore, one degree Centigrade occupies one centimeter, although the apparatus to which these sheets belong is no larger than a small self-registering manometer.

These figures show, also, that the sensitiveness increases rapidly with increase of temperature, for the distance from 43 deg. to 44 deg. is about five times as great as that from —5 deg. to —4 deg.

This instrument is capable, without any change in the dimensions of its essential parts, of recording temperatures through an interval of 90 deg. C., from —30 deg. to +60 deg. But to do this without any loss of sensitiveness would require a drum 58 centimeters in height. It is preferable to arrange matters so that the temperatures desired shall fall on a cylinder 10 or 20 centimeters in height. The regulating screw, W, enables the indications of the recording pen to be adjusted once for all, by the aid of a standard thermometer and one of my thermo-regulators.

The utility of the instrument is by no means restricted to low and medium temperatures such as have been mentioned in order to illustrate its sensitiveness. Its upper limit is determined only by the melting point of the material which forms the sensitive reservoir, for the thermometric liquid may be a fused metal.

For use at high temperatures this reservoir is formed of two tubes, A and B (Fig. 5), of porcelain or other refractory material, connected by a third tube, D, of small internal diameter. The upper part, E F, of the tube B is inclined and its upper end is connected by a small tube, F C, of porcelain, iron, or nickel, with the top of the bulb, C.

This bulb is also connected with the long flexible tube, f, which leads to the motor tube of the instrument, and, like these tubes, is filled with mercury or other inert liquid.

To charge the reservoir the tube, F C, is detached from the bulb, C, the tubes, A and D, are then filled with a metal of suitable melting point, the bulb is re-

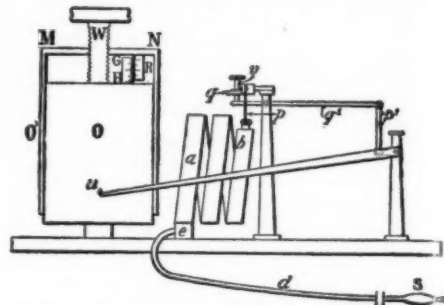


FIG. 3.—SELF-REGISTERING THERMOMETER.

attached and the space, N B E F C, is filled with compressed nitrogen, hydrogen or air, which is forced in through the cock, R.

In order to fix the ideas let us suppose that we wish to measure temperatures approximating to 1,200 deg. or 1,300 deg. C., and that the tube, A, is filled with silver. The reservoir is placed in the blast furnace or cupola of which the temperature is sought, the inclined portion, E F, passing through the wall of the furnace, as shown in Fig. 5. Silver melts at 1,050 deg. C. and forms vapor at all higher temperatures. In the space, B E F, the pressure of this vapor will be, according to Watt's principle, the pressure which corresponds to the coldest part of that space, F, and will therefore be inconsiderable. In A, on the contrary, the silver vapor will be saturated, that is, it will have the maximum pressure corresponding to the temperature of the furnace, and this pressure, transmitted by the liquid silver in D, will compress the gas in the space, N B E F C, which, in turn, will transmit the pressure to the mercury in f and the distant motor tube. In other words, everything occurs in the same way as if the saturated silver vapor acted upon the incompressible liquid in f directly, instead of through the molten silver and a column of gas. This modification permits temperatures as high as 1,500 deg. C. to be measured as accurately as low temperatures. For temperatures lower than 1,100 deg. C. the reservoir may be made of iron or nickel, instead of porcelain.

Because of their principle of action and their ability to indicate temperature at a distance, these vapor thermometers will certainly prove very useful both in measurements of precision and in manufactures. The following are some of their applications: the working of iron, steel, and other metals in the blast furnace, the smelting furnace and the crucible; ceramic manufactures and allied industries; sugar making, distilling, the manufacture of liquors, cordials, and extracts; brewing and fermentation in general; manufacture of rubber, vulcanizing, waterproofing fabrics, etc.; drying of wood, leather, paper, and articles of food; manufacture and fermentation of tobacco; manufacture of drugs and chemicals.

In medical practice they enable the physician to

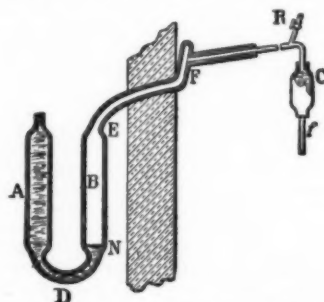


FIG. 5.—SILVER VAPOR PYROMETER.

take a patient's temperature with very great accuracy without touching the apparatus. The length of the communicating tube and the size and shape of the sensitive bulb may be varied to suit special uses. With the self-registering thermometer a continuous record of bodily temperature may be made in the physician's absence without inconveniencing the patient even when he is immersed in a bath, as in typhoid fever, or is under the influence of chloroform, during an operation. Surgeons and nurses will find the instruments

useful in determining the temperature of sterilizing and disinfecting ovens, and baths of all sorts.

The applications to household uses and personal hygiene are also interesting and important.

Finally, there are cases in which the ability to determine temperatures at very distant points may be of

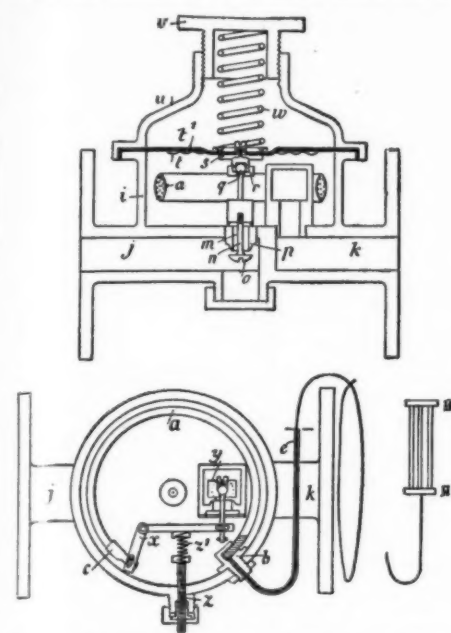


FIG. 6.—VERTICAL AND HORIZONTAL SECTIONS OF THERMO-REGULATOR FOR STEAM HEATING.

inestimable value. For example, the manager of a factory may sit at his desk and learn at any instant, by a mere glance at a dial or a cylinder, the temperature and consequently the pressure in any steam boiler. In this case the apparatus affords a remarkable safeguard and means of control.

THERMO-REGULATORS.

The substitution of vapor tension for expansion is even more advantageous in the regulation of temperature than in its measurement. The long and tedious corrections made necessary by the change of volume do not prevent expansion thermometers from giving good results in skillful hands but they almost prohibit the employment of expansion thermostats, which have to satisfy certain special conditions to which thermometers are not subject.

The essential organ of the vapor thermostat, as of the vapor thermometer, is a tube bent into the form of a ring and connected with a long, flexible tube which permits the regulation to be made at a distance. These tubes are arranged and filled in the manner already described. The free end of the ring-shaped tube, however, instead of moving a pointer over a dial or a pen on a rotating drum, operates a valve which controls the draft of a chimney or the flow of the heating fluid, gas, hot air, hot water, steam, etc.

It is clear that if the valve which admits the heating fluid to an apartment is made to close completely at a certain temperature the apartment can not attain a higher temperature. If, on the other hand, the apparatus is so arranged that a slight lowering of temperature causes the valve to be thrown wide open, the cooling will be quickly compensated by an increased flow of the heating fluid, so that the temperature of the apartment will remain practically constant.

Three types of apparatus suffice for all the demands of practice.

Fig. 6 illustrates the form designed for steam or other fluid at considerable pressure. One end of the motor tube is fastened to the bottom of a cast-iron box, *i*, which is connected with the steam pipes, *j* and *k*. The mouth, *m*, of the supply pipe, *j*, is furnished with a valve, *o*, fitting a beveled seat, *p*. The valve rod, *n*,

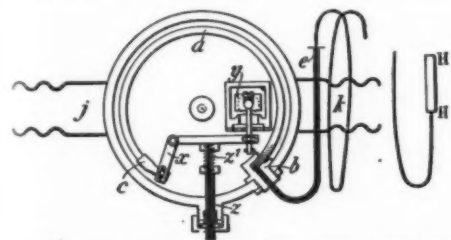


FIG. 7.—THERMO-REGULATOR FOR HEATING BY COAL GAS OR ACETYLENE.

is attached by a ball and socket joint to the corrugated sheet metal top, *t*, of the box, *s*. To prevent the deformation or rupture of this flexible top it may be protected by a wire netting, *v'*, the edges of both being clamped between the rim of the box and that of its cover, *u*. A screw plug, *V*, in the neck of this cover serves to regulate the pressure, and therefore the flow of steam for any given temperature. The free end, *c*, of the motor tube controls, through the lever, *a*, a second valve, *y*, which regulates the flow of steam from

the box into the pipe, K , leading to the radiators. The flexible tube, e , of indefinite length, passes through the side of the regulator box, i , and terminates in the sensitive organ, or vapor reservoir, in the apartment which is to be kept at constant temperature. The adjusting screw, z , acting upon the spring, z' , permits the temperature for which the closure of the valve is complete to be varied to a slight extent.

The action of the apparatus is as follows: The steam, arriving by either of the pipes, *j* and *k*, but preferably by the former, enters the regulator box at a pressure determined by the tension of the spring, *v*, and passes out through the valve, *y*, into the outflow pipe and the radiators. So long as the temperature in the inclosure or apartment to be heated is lower than the temperature for which the apparatus is designed this valve, *y*, remains open, but it closes when the desired temperature has been attained. The closure of the valve, *y*, produces an increased pressure in the box which instantly causes the valve, *o*, to close and shut off the supply of steam. A slight lowering of temperature in the inclosure or apartment to be heated reopens the valve *y*, whereupon the valve, *o*, reopens also and the steam flows through the regulator to the radiators as at the beginning, and so on, indefinitely.

It should be noted that, independently of the advantages which accrue directly from the application of the elastic force of saturated vapor, the apparatus just described eliminates a very serious defect which would alone suffice to make precision impossible in the regulation of temperature when the heating is effected by steam or other fluid under pressure. This defect is due to the differences in the force exerted by the steam upon the valves which control its flow at different phases of motion of these valves. Every steam fitter must have observed the consequences of this defect, the exact cause of which appears to be unknown since the defect is found in all existing apparatus. In the apparatus here described, however, it is evident that the forces exerted on the valves by the steam remain practically constant, so that the serious inconveniences resulting from the defect specified are removed.

The second and simpler form of thermo-regulator rep-

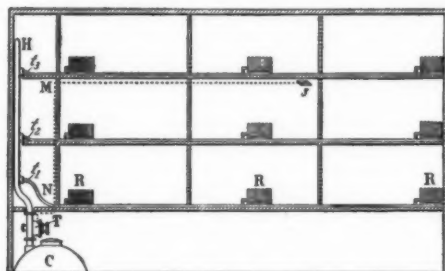


FIG. 8.—STEAM HEATING SYSTEM CONTROLLED BY A SINGLE THERMOREGULATOR.

resented in Fig. 7 differs from the first by the substitution of a rigid top for the corrugated flexible sheet of metal and the omission of the valve. *o*. It is designed chiefly for apartments or other inclosures heated by means of ordinary illuminating gas, acetylene, or other fluid at low pressure.

The third form consists merely of the motor tube with a multiplying train of wheels or levers connected with its free end. Fig. 9 illustrates its application to the valve, *h*, of a hot-air pipe, *H*.

APPLICATIONS OF THE THERMO-REGULATOR.

The first form is applicable to the heating, by steam or any other fluid at any pressure, of apartments, hot-houses, drying rooms, ovens of any desired temperature, as used in various industries, and railway cars. It will also serve to maintain a constant temperature in rooms which are cooled by the evaporation of liquid carbonic acid, ammonia, sulphurous acid, etc.

Fig. 8, which represents a system of steam heating, will also make clear the use and the function of the thermo-regulator in other cases.

A steam heating system consists essentially of a so-called low-pressure boiler, which generates steam usually at a pressure between 4 and 28 pounds to the square inch; a number of radiators, each composed of a sheaf of pipes, a cylinder with branches, or a chest with a large radiating surface; and a system of pipes to convey the steam to the radiators and to conduct the water of condensation back to the boiler, which is usually placed in the cellar. From the boiler the steam passes into a large pipe, *T H*, from which one or more branch pipes, leading to the radiators, diverge at each story.

With this system one or more thermo-regulators may be employed, according to the rigor with which constancy of temperature is to be maintained. Fig. 8 illustrates the regulation of the temperature of an entire building by one thermo-regulator, T , attached to the main steam pipe, between the boiler and the first branch. The long flexible tube of the thermo-regulator, indicated by the dotted line, $T N M S$, runs along walls and ceilings, like an electric-light wire, to a central room in which the sensitive organ, or vapor reservoir, S , is placed. It should be noted that the apparatus is not at all in the way, for the reservoir S consists of three metal tubes twelve inches long and a quarter of an inch in diameter, and the external diameter of the long connecting tube does not exceed one-sixth of an inch.

This arrangement with a single thermo-regulator will suffice for many cases occurring in practice, for example, a workshop, store, or factory, where each story consists of a single room or a number of communicating rooms, but it may prove insufficient where the rooms do not communicate with each other so that the cooling produced by opening an outer door in one room cannot quickly affect the instrument in the central room.

In all cases in which great constancy of temperature is required a thermo-regulator should be attached to each of the branch pipes, t_1 , t_2 , t_3 , and where it is desired to maintain different rooms at different temperatures a thermo-regulator should be placed in each room. In a railway train heated by steam from the

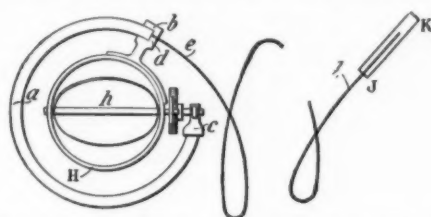


FIG. 9.—THERMO-REGULATOR APPLIED TO HOT-AIR PIPE OR CHIMNEY DRAFT.

locomotive each car must have its separate thermostat.

The second type of apparatus (Fig. 7) is adapted chiefly to cases in which the heating agent is a gas at low pressure, such as coal gas or acetylene.

Among its applications are:

(a) In medicine, surgery, and dentistry.—To medical, surgical, obstetrical and gynecological therapeutics, sterilization of instruments and bandages by dry or moist heat, preparation of lotions, vulcanizing dental plates, etc.

(b) In the household.—To heating rooms and baths, and cooking.

(c) In manufacturing chemistry.—To the manufacture of a great many drugs and chemicals, and in chemical laboratories of every kind.

In all of these applications the installation and use of the apparatus are very simple. It is only necessary to cut the gas pipe and connect the severed ends to the tubes, *j* and *k*. (Fig. 7.) The sensitive reservoir, *H H*, is placed in the room or vessel which it is desired to keep at a constant temperature. Fig. 10 illustrates the application of the apparatus to a water bath heated by gas which is conducted to the burner and the thermo-regulator (on the left) by rubber tubes. The vapor reservoir is immersed in the bath.

The third model, the simplest of all, is directly applicable to the heating of apartments by hot air or hot water, the heating of railway cars with the thermo-syphon, the regulation of the temperature of apartments heated by stoves burning coal, coke, petroleum, alcohol, or other fuel, the cooling of apartments by currents of cold air, etc.

In all these and similar cases the function of the apparatus consists in controlling a valve according to the temperature. In heating with hot air or hot water, and in cooling with cold air, this valve governs the flow of the heating or cooling fluid. In heating by a stove the valve regulates the draft. Fig. 9 illustrates the application of the apparatus to a hot-air heater. The arrangement in other cases is not difficult to understand.

This form of thermo-regulator provides a second method of regulating the temperature of steam-heated rooms. Instead of controlling the admission of steam into the apartment, as in Fig. 8, with the regulator shown in Fig. 6, we may employ the simpler apparatus (Fig. 9) to regulate the draft of the fire with reference to the temperature of the apartment to be heated. Every good steam-heating system includes a draft-

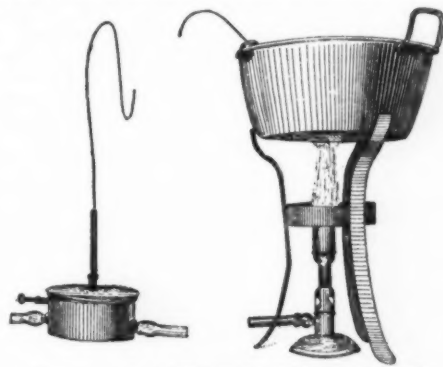


FIG. 10. GAS-HEATED WATER BATH
CONTROLLED BY THERMO-REGULATOR.

regulating device, but the draft is made to depend on the temperature of the boiler instead of that of the room to be heated—a fact which makes an immense difference, both in constancy of temperature and in economy. If the draft of the furnace is regulated by the variations in the temperature of the apartment to be heated no more fuel is consumed than the exact quantity required to heat that apartment to the desired degree.

The operation of all the thermo-regulators which

have been described is altered in no respect when we pass from moderate temperatures to the highest temperatures employed in the arts. By the substitution of the reservoir of metallic vapor which was described in connection with thermometers and pyrometers the thermo-regulator also may be adapted to the service of the metallurgy of iron, steel, and other metals. In such operations the apparatus is applied to the tweyers or other draft-producing devices.

In many industries the use of a thermostat, or thermo-regulator, is necessary because the excellence of the product depends upon the maintenance of a constant temperature during its production. Among such industries are many chemical manufacturers, vulcanizing, artificial incubation, etc., in which the lack of a reliable thermo-regulator necessitates constant supervision and laborious regulation by hand.

The advantages of maintaining constant temperature in living rooms are less obvious, yet the injury done to the health of the occupants by great changes in temperature justifies the taking of all possible precautions against the occurrence of such changes, which lead to many painful and tedious diseases, including pneumonia, pleurisy, bronchitis, colds, sore throat, etc. It is an error to suppose that these maladies are contracted in the open air. They usually originate indoors where active exercise is impossible. It is certain that the apparatus described above may render good service to persons careful of their health.

From the viewpoint of economy these devices appear equally useful. In fact, whether the heating is effected by steam or otherwise, as the consumption of fuel is controlled directly by the variations in the temperature of the apartment to be heated, the employment of these thermo-regulators assures the greatest possible economy of fuel, of which no more is burned than is needed to maintain the desired temperature.

Furthermore, as these thermo-regulators, in virtue of the principle on which they are based, are instruments of precision, they will render great services of another character, not only to manufacturers, but also to scientists, who often find it difficult to secure a desired constancy of temperature, especially when this must be maintained, in ovens or baths of considerable dimensions, for several days and nights.—Abstracted for SCIENTIFIC AMERICAN SUPPLEMENT from La Science au XXme Siècle.

EVOLUTION AND INANIMATE MATTER.

By PROF. G. H. DARWIN, F.R.S.

THE fascinating idea that matter of all kinds has a common substratum is of remote antiquity. In the Middle Ages the alchemists, inspired by this idea, conceived the possibility of transforming the baser metals into gold. The sole difficulty seemed to them the discovery of an appropriate series of chemical operations. We now know that they were always indefinitely far from the goal of their search, yet we must accord to them the honor of having been the pioneers of modern chemistry.

The object of alchemy, as stated in modern language, was to break up or dissociate the atoms of one chemical element into its component parts, and afterward to reunite them into atoms of gold. Although even the dissociative stage of the alchemistic problem still lies far beyond the power of the chemist, yet modern researches seem to furnish a sufficiently clear idea of the structure of atoms to enable us to see what would have to be done to effect a transformation of elements. Indeed, in the complex changes which are found to occur spontaneously in uranium, radium, and the allied metals we are probably watching a spontaneous dissociation and transmutation of elements.

Natural selection may seem, at first sight, as remote as the poles asunder from the ideas of the alchemist, yet dissociation and transmutation depend on the instability and regained stability of the atom, and the survival of the stable atom depends on the principle of natural selection.

Until some ten years ago the essential diversity of the chemical elements was accepted by the chemist as an ultimate fact, and indeed the very name of atom, or that which cannot be cut, was given to what was supposed to be the final indivisible portion of matter. The chemist thus proceeded in much the same way as the biologist who, in discussing evolution, accepts the species as his working unit. Accordingly, until recently the chemist discussed working models of matter of atomic structure, and the vast edifice of modern chemistry has been built with atomic bricks.

But within the last few years the electrical researches of Lenard, Röntgen, Becquerel, the Curies, of my colleagues Larmor and Thomson, and of a host of others, have shown that the atom is not indivisible, and a flood of light has been thrown thereby on the ultimate constitution of matter. Among all these fertile investigators it seems to me that Thomson stands pre-eminent, because it is principally through him that we are to-day in a better position for picturing the structure of an atom than was ever the case before.

It has been shown, then, that the atom, previously supposed to be indivisible, really consists of a large number of component parts. By various convergent lines of experiment it has been proved that the simplest of all atoms, namely that of hydrogen, consists of about 800 separate parts; while the number of parts in the atom of the denser metals must be counted by tens of thousands. These separate parts of the atom have been called corpuscles or electrons, and may be described as particles of negative electricity. It is paradoxical, yet true, that the physicist knows more about these ultra-

atomic corpuscles and can more easily count them than is the case with the atoms of which they form the parts.

The corpuscles, being negatively electrified, repel one another just as the hairs on a person's head mutually repel one another when combed with a vulcanite comb. The mechanism is as yet obscure whereby the mutual repulsion of the negative corpuscles is restrained from breaking up the atom, but a positive electrical charge, or something equivalent thereto, must exist in the atom, so as to prevent disruption. The existence in the atom of this community of negative corpuscles is certain, and we know further that they are moving with speeds which may in some cases be comparable to the velocity of light, namely, 200,000 miles a second. But the mechanism whereby they are held together in a group is hypothetical.

It is little more than a year ago that Thomson suggested, as representing the atom, a mechanical or electrical model the properties of which could be accurately examined by mathematical methods. He would be the first to admit that his model is at most merely a crude representation of actuality, yet he has been able to show that such an atom must possess mechanical and electrical properties which simulate, with what Whetham describes as "almost Satanic exactness," some of the most obscure and yet most fundamental properties of the chemical elements. "Se non è vero, è ben trovato," and we are surely justified in believing that we have the clue which the alchemists sought in vain.

Thomson's atom consists of a globe charged with positive electricity, inside which there are some thousand or thousands of corpuscles of negative electricity, revolving in regular orbits with great velocities. Since two electrical charges repel one another if they are of the same kind, and attract one another if they are of opposite kinds, the corpuscles mutually repel one another, but all are attracted by the globe containing them. The forces called into play by these electrical interactions are clearly very complicated, and you will not be surprised to learn that Thomson found himself compelled to limit his detailed examination of the model atom to one containing about seventy corpuscles. It is indeed a triumph of mathematical power to have determined the mechanical conditions of such a miniature planetary system as I have described.

It appears that in general there are definite arrangements of the orbits in which the corpuscles must revolve, if they are to be persistent or stable in their motions. But the number of corpuscles in such a community is not absolutely fixed. It is easy to see that we might add a minor planet, or indeed half a dozen minor planets, to the solar system without any material derangement of the whole; but it would not be possible to add a hundred planets with an aggregate mass equal to that of Jupiter without disorganization of the solar system. So also we might add or subtract from an atom three or four corpuscles from a system containing a thousand corpuscles moving in regular orbits without any profound derangement. As each arrangement of orbits corresponds to the atom of a distinct element we may say that the addition or subtraction of a few corpuscles to the atom will not effect a transmutation of elements. An atom which has a deficiency of its full complement of corpuscles, which it will be remembered are negative, will be positively electrified, while one with an excess of corpuscles will be negatively electrified. I have referred to the possibility of a deficiency or excess of corpuscles because it is important in Thomson's theory; but, as it is not involved in the point of view which I wish to take, I will henceforth only refer to the normal or average number in any arrangement of corpuscles. Accordingly we may state that definite numbers of corpuscles are capable of association in stable communities of definite types.

An infinite number of communities are possible, possessing greater or lesser degrees of stability. Thus the corpuscles in one such community might make thousands of revolutions in their orbits before instability declared itself; such an atom might perhaps last for a long time as estimated in millionths of seconds, but it must finally break up and the corpuscles must disperse or re-arrange themselves after the ejection of some of their number. We are thus led to conjecture that the several chemical elements represent those different kinds of communities of corpuscles which have proved by their stability to be successful in the struggle for life. If this is so, it is almost impossible to believe that the successful species have existed for all time, and we must hold that they originated under conditions about which I must forbear to follow Sir Norman Lockyer in speculating.*

But if the elements were not eternal in the past, we must ask whether there is reason to believe that they will be eternal in the future. Now, although the conception of the decay of an element and its spontaneous transmutation into another element would have seemed absolutely repugnant to the chemist until recently, yet analogy with other moving systems seems to suggest that the elements are not eternal.

At any rate it is of interest to pursue to its end the history of the model atom which has proved to be so successful in imitating the properties of matter. The laws which govern electricity in motion indicate that such an atom must be radiating or losing energy, and therefore a time must come when it will run down, as a clock does. When this time comes it will spontaneously transmute itself into an element which needs less energy than was required in the former state. Thomson conceives that an atom might be constructed after his model so that its decay should be very slow.

* "Inorganic Evolution," (Macmillan, 1900.)

it might, he thinks, be made to run for a million years, but it would not be eternal.

Such a conclusion is an absolute contradiction to all that was known of the elements until recently, for no symptoms of decay are perceived, and the elements existing in the solar system must already have lasted for millions of years. Nevertheless, there is good reason to believe that in radium, and in other elements possessing very complex atoms, we do actually observe that break-up and spontaneous re-arrangement which constitute a transmutation of elements.

It is impossible as yet to say how science will solve this difficulty, but future discovery in this field must surely prove deeply interesting. It may well be that the train of thought which I have sketched will ultimately profoundly affect the material side of human life, however remote it may now seem from our experiences of daily life.

I have not as yet made any attempt to represent the excessive minuteness of the corpuscles, of the existence of which we are now so confident; but, as an introduction to what I have to speak of next, it is necessary to do so. To obtain any adequate conception of their size we must betake ourselves to a scheme of three-fold magnification. Lord Kelvin has shown that, if a drop of water were magnified to the size of the earth, the molecules of water would be of a size intermediate between that of a cricket-ball and of a marble. Now each molecule contains three atoms, two being of hydrogen and one of oxygen. The molecular system probably presents some sort of analogy with that of a triple star; the three atoms, replacing the stars, revolving about one another in some sort of dance which cannot be exactly described. I doubt whether it is possible to say how large a part of the space occupied by the whole molecule is occupied by the atoms; but perhaps the atoms bear to the molecule some such relationship as the molecule to the drop of water referred to. Finally, the corpuscles may stand to the atom in a similar scale of magnitude. Accordingly a threefold magnification would be needed to bring these ultimate parts of the atom within the range of our ordinary scales of measurement.

I have already considered what would be observed under the triply powerful microscope, and must now return to the intermediate stage of magnification, in which we consider those communities of atoms which form molecules. This is the field of research of the chemist. Although prudence would tell me that it would be wiser not to speak of a subject of which I know so little, yet I cannot refrain from saying a few words.

The community of atoms in water has been compared with a triple star, but there are others known to the chemist in which the atoms are to be counted by fifties and hundreds, so that they resemble constellations.

I conceive that here again we meet with conditions similar to those which we have supposed to exist in the atom. Communities of atoms are called chemical combinations, and we know that they possess every degree of stability. The existence of some is so precarious that the chemist in his laboratory can barely retain them for a moment; others are so stubborn that he can barely break them up. In this case dissociation and re-union into new forms of communities are in incessant and spontaneous progress throughout the world. The more persistent or more stable combinations succeed in their struggle for life, and are found in vast quantities, as in the cases of common salt and of the combinations of silicon. But no one has ever found a mine of gun-cotton, because it has so slight a power of resistance. If, through some accidental collocation of elements, a single molecule of gun-cotton were formed, it would have but a short life.

Stability is, further, a property of relationship to surrounding conditions; it denotes adaptation to environment. Thus salt is adapted to the struggle for existence on the earth, but it cannot withstand the severer conditions which exist in the sun.—Abstracted from the Inaugural address delivered by the President of the British Association for the Advancement of Science.

A SOAP SOLUTION FOR DETERMINING THE HARDNESS OF WATER.

J. PIERVAERTS (Apotheker Zeitung) says that a solution perfectly adapted to this purpose, and one which, differently from others, may be kept a long time, is prepared as follows:

35 cubic centimeters of almond oil are mixed with 50 cubic centimeters of glycerin, of 1.26 specific weight, and 8.5 cubic centimeters of 50 per cent soda lye, and boiled to saponification. To this mixture, when it has cooled to from 85 to 90 deg. C., are added 100 to 125 cubic centimeters of boiling water. After cooling again, 500 cubic centimeters of water is added, and the solution is poured into a one-liter flask, with 94 per cent alcohol to make up one liter. After standing two months it is filtered. Twenty hydrometer degrees of this solution make, with 40 cubic centimeters of a solution of 0.55 gramme of barium chloride in 1 liter of water, a dense lather 1 centimeter high.

TO DARKEN ALUMINIUM SHEETS.

In order to impart a dark color to aluminium plate, the following process is used: The surface of the sheet to be colored is polished with very fine emery powder or finest emery cloth. After the polishing pour a thin layer of olive oil over the surface and heat slowly over a spirit flame. In the case of large sheets, they must, of course, be heated in the drying oven. After a short while pour on oil again, in order to obtain absolute

uniformity of the coating, and heat the plate once more. Under the action of the heat the plate turns first brown, then black, according to the degrees of heat. When the desired coloration has been attained, the plate is polished over again, after cooling, with a woolen rag or soft leather.—*Werkmeister Zeitung*.

TRADE NOTES AND FORMULÆ.

Composition of Reliable Baths for Galvanostegy.—Nickeling.—The following tried bath is recommended for this purpose: Nickel sulphate 40 grammes, ammonium chloride 25 grammes, boric acid 10 grammes, citric acid 10 grammes; dissolve in water, and fill up to one liter of liquid. In this bath the boric acid has a very favorable action.

Silvering.—A little potassium cyanide and some mono-basic potassium citrate in powder form is added from time to time to the bath generally used, which is prepared by dissolving freshly precipitated silver cyanide in a potassium cyanide solution.

Coppering.—Those baths which contain cyanide work best, and may be used for all metals. The amount of the latter must not form too large an excess. The addition of a sulphite is very dangerous. It is of advantage that the final bath contain an excess of alkali, but only as ammonia or ammonium carbonate. For a copper salt the acetate is preferable. According to this, the solution A is prepared in the warm, and solution B is added with heating. Solution A: Neutral copper acetate 30 grammes, crystallized sodium sulphite 30 grammes, ammonium carbonate 5 grammes, water 500 grammes. Solution B: Potassium cyanide (98 to 99 per cent) 35 grammes, and water 500 grammes.

Brassing.—The following receipt is recommended for the bath: Copper acetate 50 grammes, dry zinc chloride 25 grammes, crystallized sodium sulphite 250 grammes, ammonium carbonate 35 grammes, potassium cyanide 110 grammes; dissolve in three liters of water.

Gilding.—The best bath is obtained by precipitating a solution of pure brown gold chloride with ammonia, and dissolving the fulminating gold in a one per cent solution of potassium cyanide. The solution is then brought to a boil. The quantity of gold must amount to at least one gramme in one liter. When red gilding is wanted, 0.5 of copper acetate is added for each gramme of gold.

Platinizing.—For this purpose chloro-platinate of potassium, PtCl_2KCl , is given the preference. The salt occurring in commerce, which is merely dissolved in water, may be used; at least two grammes of platina-salt in one liter of water. The platinic chloride solution, previously heated for a long time with neutral potassium oxalate, may also be employed.

Steeling.—The following bath is used: Pure crystallized ferrous sulphate 40 grammes and ammonium chloride 100 grammes in 1 liter of water. It is of advantage to add to this 100 grammes of ammonium citrate, in order to prevent the precipitation of basic iron salts, especially at the anode.—*Chemiker Zeitung*.

Protecting Coat for Wood and Metals.—A preparation for protecting wood against the action of fire and of moisture, and also for producing on the surface of wood and metal a coat, insulating with reference to electricity and preservative from corrosion, has been introduced in France by Louis Bethisy and Myrthil Rose.

The bases or fundamental raw materials, quite distinct from those hitherto employed for the same purpose, are 100 parts by weight of nitro-cellulose and 30 parts by weight of chloride of lime, dissolved in 50 per cent alcohol.

Preparation of the Bases.—The cellulose (of wood, paper, cotton, linen, ramie, or hemp) is put in contact with two-thirds part of sulphuric acid of 66 deg. B. and one-third part of nitric acid of 42 deg. for some twenty or thirty minutes, washed with plenty of water, and kept for twenty-four hours in a tank of water supplied with an energetic current.

The nitro-cellulose thus obtained is bleached for this purpose; a double hypochlorite of aluminium and magnesium is made use of. This is obtained by grinding together 100 kilogrammes of chloride of lime, 60 kilogrammes of aluminium sulphate, 23 kilogrammes of magnesium sulphate, with 200 kilogrammes of water.

When the nitro-cellulose is bleached and rewashed, it is reduced to powder and dried as thoroughly as possible. It is placed then in a vat hermetically closed, and put in contact with the indicated proportion of calcium chloride dissolved in alcohol. This solution of calcium chloride should be prepared at least twenty-four hours in advance and filtered.

Composition of the Coating.—This has the following constituents: Bases (nitro-cellulose and solution of calcium chloride) 1 kilogramme; amyl acetate (solvent of the bases), 5 kilogrammes; sulphuric ether of 65 deg., 1.650 kilogramme; alcohol, 0.850 kilogramme; one of these powders, alum, talc, asbestos, or mica, 0.100 kilogramme. Other solvents may be employed instead of amyl acetate; for example, acetone, acetic acid, ether alcohol, or methyl alcohol. The ether alcohol furnishes a product drying very quickly. If a very pliant coating is desired, the amyl acetate is employed preferably, with addition of vaseline oil, 0.20 kilogramme, and lavender oil, 0.010 kilogramme.

Method of Operating.—The sulphuric acid is mixed with the alcohol, and left for an hour in contact, shaking from time to time. Afterward the amyl acetate is added, and left in contact for another hour under similar agitation. In case of the employment of vaseline oil and lavender oil, these two are mingled in ether alcohol. The base is introduced and left in con-

tact for twenty-four hours, with frequent agitation. The fluidity of the product is augmented by increasing the quantity of the solvent.

Properties.—Wood covered with this coating is fire-proof, non-hygrometric, and refractory to the electric current. It also resists the action of acids and alkalis. Metals covered with it are sheltered from oxidation, and effectually insulated on their surface from the electric current. The coating is liquid in form, and applied like collodions, either by the brush or by immersion or other suitable method.

SCIENCE NOTES.

The Bureau of Soils is mapping our various areas to the end that the residents on each may as soon as possible learn the peculiarities with which they have to deal. This work is comparatively new. Its value has been overlooked by the educator. A force of soil experts is being trained in the Department of Agriculture to help the cultivator to a better knowledge of the possibilities of his acres throughout our broad land, in order that run-down lands may be reclaimed and that the fertility of our newer lands may be maintained to meet the requirements of a rapidly increasing population.

The feature of our globe which is now, broadly speaking, most accurately laid down is the coast line. The safety of navigation has caused general marine surveys to be carried on all over the world during the nineteenth century, which have finally determined the position and shape of the boundaries of the sea. These surveys, executed for the most part by skilled naval officers with proper instrumental outfit, and supplied especially with trustworthy chronometers, and based upon frequent carefully determined astronomical positions, have resulted in this boundary line being delineated with an accuracy, so far as its absolute position is concerned, far in advance of any other main feature in maps.

With the piston valve we get a better balance of the valve, which makes it easier to handle and decreases the wear and tear on the motion work of a locomotive. With the increased size of engines and steam pressure, the ordinary D balance valve increases in size proportionately, and while we may balance a slide valve in the same ratio as the valves on smaller engines, the difference in the unbalanced surface increases with the size of the engine and this increases the wear on the valve, link motion, and eccentric straps, and increases the work necessary on the part of the engineer to handle the engine. This being a fact, a great deal of trouble is experienced in keeping the valves on our slide-valve engines square, while on the other hand, we do not experience trouble of this kind with the piston valve until after the engine has been out of the shop for a long while and the parts become badly worn. With the use of the inside admission piston valve we do away with the metallic valve stem packing, which means a great saving, as we only have the exhaust pressure on the packing side, and the fibrous packing answers the purpose and lasts a long while. With the slide valve on large engines we can hardly exceed 25,000 miles before the valves need facing, and oftentimes sooner than that. When this has to be done, it means the loss of the use of the engine for a day at least with a cost of \$12 to \$14 for labor, while with the piston valve, if the rings are broken or need attention, the valve can be removed, new rings applied in from thirty to forty minutes, and the engine is ready for service again. An advantage of the piston valve over the slide valve is the accessibility to its parts. When an engine needs its valves reset after running some time, the port marks on the valve stem become obscured, and possibly the man who is about to do the work has a different tram or wants to get different marks on the stem. With the slide valve engine the machinist has to use the block and tackle and raise the covers of the steam chest before he can make his new marks, while with the piston valve he simply has to remove two plugs on each end of the chest leading directly to the edge of the steam port. This means a saving of time, and time is valuable in a busy shop or roundhouse.

In a paper recently read before the Académie des Sciences, M. Bernard Brunhes describes some researches he made which seem to show that the direction of the earth's magnetism has changed considerably in the recent epochs. The author and M. David had previously noted certain cases in which a flow of volcanic lava upon a layer of clay had transformed it into natural brick. It was shown here that the direction of magnetization in such a stratum of metamorphic clay is in general well defined and different from the present direction of the earth's magnetic field at the place where the stratum is located. In the second place, the direction of the permanent magnetic field is the same in the brick and in the volcanic rock, basalt, andesite, etc., which had formed the flow and then cooled off. The writers think that this common direction of the magnetic field is the direction which the earth's magnetic field had at the time of the lava flow. The observation of new strata of brick always confirmed the preceding results. One deposit which was especially abundant and allowed the samples to be well examined, gave besides a result which should be mentioned. It is situated in the commune of Cezens, France, near the village of Pontfarenin at about 3,300 feet altitude. The clay had been baked by a flow of basalt which took place at the Miocene epoch. Numerous specimens from the brick and also from the basalt which covered it, taken at distances of 300 feet apart, showed a uniform direction of magnetic field, with the north pole lying toward the south and at the upper

part. The inclination is therefore negative with relation to the present position of the dipping-needle; and is equal to -75 deg. It is natural to suppose that this was the inclination of the earth's field at that epoch. Up to the present, there may have been some doubt as to this point. In the course of his remarkable work upon Etruscan and Roman pottery, Folgerhalter concluded that the declination was negative in Italy five or six centuries B. C., but he only obtained negative declinations of a few degrees. In one case a vase from the Florence museum gave 14 degrees. The objections which were made to his results can scarcely apply here. The brick has remained in place and had no local overturning, as the basalt is not disturbed. Local disturbances can hardly account for the negative inclination of 75 degrees which is uniform over a layer more than 300 feet long, and a lightning stroke could hardly have caused the effect. It seems more natural to see a confirmation of Folgerhalter's results and to suppose that the inclination of the earth's field must have been negative in Europe at an early period.

ELECTRICAL NOTES.

It requires simply the passage of the electric current through a conducting medium to produce heat, the intensity of which depends upon the amount of current which passes. Inasmuch as most substances retain their conductivity at high temperatures, the degree of intensity which is theoretically possible is unlimited. Practically, however, limitations are placed upon it through the physical difficulties of keeping the conducting medium in place. While it retains its solid condition, the temperature is limited by the fusing point of the material; when fusion commences the difficulties of containing the melted material begin, and the temperature is limited by the point of vaporization. When volatilization begins, gaseous materials escape from the field of action, carrying away the heat as rapidly as it is supplied to the furnace as latent heat of volatilization or as energy stored up as potential chemical energy. It is true that the temperature of volatilization might be increased by subjection to high pressure, but this involves construction of a container which can be made only of solid materials, having limitations imposed by the fusing temperatures. The electric arc maintained through a carbon vapor furnishes perhaps the highest degree of temperature attainable; the temperature of which is usually considered as being definitely fixed by the volatilization of carbon. Through limitations upon our methods of measuring these high temperatures the exact value to be assigned to the temperature of the electric arc cannot be stated, though the most satisfactory measurements give values ranging between 3,600 and 4,000 deg. C. Whether this is the ultimate limit to be attained by electrical means is difficult to say. There is, of course, the possibility of exceeding it by maintaining the arc under a high atmospheric pressure, or by feeding electrical energy to the arc more rapidly than it can be dissipated by the volatilization of carbon, or, in other words, superheating the carbon vapor. Such speculation, however, is not necessary to show that the electric furnace has unbounded possibilities, since the range of temperatures below that of the ordinary arc offers an unlimited field of usefulness.

An ingenious illustration of the state of things in a watery solution of salts to which an electric current is applied has been drawn from a ball-room. The inventor of the simile says: Imagine a ball-room filled with people of both sexes, evenly distributed, some waltzing together in couples, others moving about irregularly, talking together and passing on and breaking up into changing groups and pairs. This represents the solution of the salt in its normal state, the waltzers being the undissociated molecules of the salt, the other individuals being those molecules which are dissociated into ions. All are in movement but the net result of all the movement leaves unchanged the general distribution of individuals throughout the extent of the room. Then, to represent the turning on of the current, let a sumptuous drinking bar suddenly appear at one end of the room and a gorgeous mirror at the other. The unattached individuals will at once commence a movement toward these poles of attraction—the men to the bar, the women to the mirror. Gradually, too, the waltzers or undissociated molecules will separate into their components and these will also commence their respective movements to the one pole and from the other, until after a certain lapse of time there will be a concentration of men round the drinking bar and of the women round the mirror and the numbers of the waltzers or undissociated molecules will have decreased. In the case of pads moistened with salt solution and conveying current from one part of the body to another the movements of ions are as follows: At the positive pole sodium moves inward, penetrating the surface in contact with the positive pad on its march to the negative pole, and chlorine moves outward, reaching the metal backing of the pad, and there is either liberated as free chlorine or else enters into combination with the metal to form a chloride. The phenomena at the negative pad are the complements of those at the positive—chlorine ions entering the skin and tissues, sodium ions moving to the metal backing of the pad and there appearing as metallic sodium, though rapidly suffering immediate decomposition from reaction with the water which exists there. If the body to be introduced through the skin be a kath-ion or positively charged ion it will migrate from the anode, and the substances which enter from the anode are the ions of the metals, of

the alkalies and of the alkaloïds; while among those which may be usefully introduced from the kathode are salicylic acid and other acid radicles. In order to introduce ions of zinc into a given area the proper procedure is to apply a pad of lint or of cotton wool moistened with a solution of a zinc salt and to bring to the outer surface of the pad a rod or plate of metallic zinc connected to the positive pole of a battery. The current which flows is carried by the zinc ions of the solution which migrate inward through the skin and, their place being supplied by fresh zinc ions set free from the zinc electrode, there is no fear of exhaustion of the supply, or of the contamination of the pad by ions of other metals, as would be the case if the metal used for the electrode were not zinc but copper or any other soluble metal. When the substance to be introduced is one like quinine or salicylic acid the supply of its ions must be maintained by the provision of an ample quantity of its solution in the fluid of the moistened pad and the metal of the electrode must be of platinum in order that extraneous ions may not complicate the process. Carbon disks or plates, if thoroughly pure, may be used instead of platinum, as carbon liberates no ions under the conditions of the experiment.

ENGINEERING NOTES.

Test and practice have proved that fine insoluble powders, when fed into boiling water, will cause foaming. While it has been customary to attribute this to alkaline water, we may conclude that it is the loosened scale matter and the floating particles in boilers that are mostly responsible for foaming, and when a sudden reduction of pressure outside of the boiler may carry off the steam in any quantity, the water saturated with air or gas will boil with great disturbance, while the animal matter or sewage-contaminated water put into the boiler will also produce priming.

Cantilever bridges are generally suitable for long spans only; where the length required is too great for a simple truss, or where it becomes necessary to erect without temporary supports, and the conditions are not favorable for an arch. It, perhaps more than any other kind, has been erected in places where simple trusses would have been more appropriate, and freaks of this kind may be seen in various places. As the cantilever bridge is not as economical as a simple truss, except for spans of great length, and as simple trusses in many cases can be erected on the cantilever principle, the simple truss is generally preferable to the pure cantilever type. The Athlone Bridge, and the bridge recently erected over the Ohio River on the line of the Baltimore & Ohio Railroad at Benwood, are examples of this kind of construction.

In any type of boiler it is of great importance to keep the tubes and other surfaces free of soot and scale, otherwise a large loss may be sustained. It is a mistake to depend entirely on the steam blower or tube cleaner, which only removes the loose soot, a scraper being necessary for occasional use to free the hard scale which will in time accumulate on the fire surfaces. It is necessary to point out that scale, or, worse still, oil on the inside of a boiler may be a source of great loss, experience having proved that even a thin film of oil will so prevent the transfer of heat that the plates or tubes will be burned in a very short time. Nothing but pure water should be used for making steam, and the practice of making the boiler do duty as a water purifier as well as a steam generator cannot be too strongly condemned. If the owners of steam plants could be made to realize that a very small deposit of soot on the outside and scale on the inside means a loss of from 10 to 20 per cent of the total fuel consumption, costing, perhaps, thousands of dollars per year, they would be convinced that it would be much cheaper to spend money in purifying apparatus, so that the scale or sediment will be removed before the water is fed to the boiler.

The "hit-and-miss" system of gas-engine regulation has been all but completely abandoned. This system, moreover, does not lend itself to working with very light charges, or with no charge, in the case of engines fed by suction gas-producers. As in these circumstances the gas supply alternates with three, four or even five strokes with no charge, it happens that the suction which determines the supply of air to the producer is not sufficiently uniform, and that the fire finishes by being extinguished, or, to say the least, by producing a very poor gas through the lack of activity in the furnace. German makers then invented the conical cam for the admission of the gas, which, being displaced by the action of the governor, produced variable lift of the gas-valve. But this device was only a variation of the stepped cam or of the stepped pecker block, which the English makers had tried in their electric types, and they soon discovered the uneconomical results it caused. The stepped arrangement had the advantage over the conical cam of lessening the work upon the governor. But, as both systems acted on the quantity of gas admitted, while the quantity of air of the mixture remained constant, mixtures of variable composition—often too rich in the case of a full charge, and always too poor with the weak charge—were formed. In the latter cases the ignitions were tardy, the diagrams bad, and the efficiency less as the charge was reduced in richness. While with a good engine regulated by the "hit-and-miss" system the consumption at half load, which from the industrial point of view is the most interesting, was not more than about 20 per cent higher per horse-power than with full load, it became 40 to 50 per cent higher with an engine with variable mixture.

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